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EFFECTS OF GREEN MANURING IN CONJUNCTION WITH FERTILIZERS ON PADDY YIELDS

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By incorporating succulent green vegetative matter into the soil just before transplanting, large quantities of ammonia are made available to the paddy crop coinciding with active growth period. Besides supplying plant nutrients, green manuring improves the physical condition of the soil, augments humus status, accelerates microbiological activity and conserves leachable, soluble constituents and soil moisture.

Among green manure crops, *dhaincha* (*Sesbania aculeata*) is specially suited for heavy paddy soils. It can withstand water logged and saline conditions.

With regard to the inorganic fertilizers, ammonium sulphate has proved to be most effective under a variety of soil types and climatic conditions. Response to phosphates on the other hand has either been small or localized to restricted areas in Hyderabad, Madhya Pradesh, parts of Bihar and Bombay. However, application of phosphate to leguminous green-manure crops has been recognised to induce and hasten their growth and also to convert phosphorus into available organic form during the process of decomposition.

With the foregoing evidence, an experiment was conducted to determine the extent of response to green manuring alone, and in conjunction with superphosphate and ammonium sulphate fertilizers.

EXPERIMENTAL PROCEDURE

The land where the investigation was carried out had a fairly high fertility built up by leguminous berseem crop grown for five years in a paddy-berseem rotation. The chemical and mechanical composition of the soil is given below:

Chemical composition	*Percentage*
Total nitrogen	0·0882
Total P_2O_5	0·2371
Available P_2O_5	0·0459
Total K_2O	0·8383
Available K_2O	0·0249
Mechanical composition	
Coarse sand	4·20
Fine sand	53·80
Silt	18·16
Clay	21·31

The analyses reveal the clay loam texture of the soil well supplied with N, P and K constituents and ideally suited for paddy cultivation.

The experiment consisted of nine treatments and six replications, and was laid out in a randomised block system.

Treatments

B_0—fallow (no green manure crop)

B_1—green manure (*dhaincha* crop)

B_2—superphosphate at 60 lb. P_2O_5 per acre applied to *dhaincha* green manure crop at sowing

N_0— 0 lb. N per acre, applied to paddy

N_1—20 lb. N ,, ,, ,, ,, ,,

N_2—40 lb. N ,, ,, ,, ,, ,,

B and N treatments comprised the following nine combinations:

$A=B_0N_0$, $B=B_0N_1$, $C=B_0N_2$, $D=B_1N_0$, $E=B_1N_1$, $F=B_1N_2$, $G=B_2N_0$, $H=B_2N_1$, $I=B_2N_2$.

Superphosphate was broadcast on the surface of the soil and placed about 6″ deep by 'Victory' inversion plough a day before sowing *dhaincha* seeds in the months of April-May depending upon the availability of irrigation water. The green manure crop was turned in late June or early July. Paddy variety N.P. 125 (early maturing, medium fine, white rice) wasraised in the nursery by mid-June. Beds 20 ft. × 15 ft. were sown at the rate of 10 maunds of paddy per acre. Transplanting was done after about one month, two seedlings per hill in lines 9-inch apart both ways. Top dressing of sulphate of ammonia was done a fortnight after transplanting, i.e. after the recovery of the seedlings. Four to five irrigations were given to the crop to supplement the rainfall of about 18 inches during the monsoon months of July, August and September. The crop was harvested by the end of October or early November.

The experiment was conducted for three years from 1952 to 1954.

EXPERIMENTAL FINDINGS

Dhaincha

Green weight of *dhaincha* in maunds per acre at burying in different years is given in Table I.

TABLE I. GREEN WEIGHT OF *DHAINCHA* IN MAUNDS PER ACRE

Treatment	1952	1953	1954	Mean
B_2	184·07	256·60	180·40	207·07
B_1	163·80	252·00	181·70	199·20
F-test	Not sig.	Not sig.	Not sig.	Not sig.
S. Em.	±7·15	±5·46	±3·57	±10·37

The data show that the application of phosphate to *dhaincha* did not significantly influence the weight of green matter per acre. The increases recorded were small and statistically not significant.

TABLE II. NITROGEN CONTENT OF *DHAINCHA* AT BURYING

Treatment	Percentage nitrogen (oven dry basis)				Nitrogen added to the soil (lb. per acre)			
	1952	1953	1954	Mean	1952	1953	1954	Mean
B_2	1·78	1·88	2·07	1·91	55·14	90·53	63·00	69·56
B_1	1·93	1·89	2·10	1·97	52·40	87·80	62·80	67·67

Table II reveals that every year there were only small variations in the nitrogen composition or total nitrogen contents between B_1 and B_2 treatments. Thus, the application of superphosphate to green manure crop did not appreciably improve the nitrogen composition or the total nitrogen content of the green matter.

Paddy

Investigations on paddy included studies on a number of effective tillers (tillers bearing earheads), height of shoot and yield of grain and straw for different treatments.

TABLE III. EFFECTS OF GREEN MANURING AND AMMONIUM SULPHATE ON THE FORMATION OF EFFECTIVE TILLERS PER CLUMP

Treatment	Effective tillers				Per cent increase Over B_0
	1952	1953	1954	Mean	
B_2	8·60	12·28	11·02	10·64	23·58
B_1	8.08	12·00	10·90	10·33	19·98
B_0	6·88	10·21	8·72	8·61	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·154	±0·226	±0·287	±0·140	Per cent increase over No.
C.D. at 5%	0·44	0·65	0·82	0·40	
N_2	7·94	12·50	10·66	10·26	9·62
N_1	7·86	11·46	10·54	9·95	6·30
N_0	7·77	10·87	9·45	9·36	..
F–test	Not sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·154	±0·226	±0·287	±0·140	..
C.D. at 5%	..	0·65	0·82	0·40	..

The data show that green manuring produced significantly greater number of tillers than no green-manuring. However, application of phosphate to green-manure crop revealed only slight and non-significant increases over green manure alone. Regarding sulphate of ammonia, its effects were masked in the first year due

to the high fertility built up by the berseem crop in the rotation. In the second year, N_2 and in the third year both N_2 and N_1 treatments were found to be significantly superior to N_0 treatment. The mean results for the three years also reveal the superiority of N_2 and N_1 over N_0 treatments.

TABLE IV. INTERACTION BETWEEN GREEN MANURING AND AMMONIUM SULPHATE EFFECTIVE TILLERS

Treatment	Effective tillers				Per cent increase over B_0N_0
	1952	1953	1954	Mean	
B_2N_2	8·60	12·80	10·90	10·81	42·05
B_2N_1	9·00	12·20	11·00	10·70	40·60
B_2N_0	8·30	11·80	11·20	10·43	37·06
B_1N_2	8·30	12·10	10·70	10·39	36·53
B_1N_1	7·90	12·50	11·30	10·54	38·50
B_1N_0	8·10	11·40	10·70	10·05	32·06
B_0N_2	6·90	11·50	10·40	9·59	26·02
B_0N_1	6·80	9·80	9·40	8·62	13·29
B_0N_0	7·00	9·40	6·50	7·61	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·267	±0·392	±0·493	±0·243	..
C.D. at 5%	0·76	1·12	1·41	0·70	..

Treatment B_2N_2 produced the maximum number of effective tillers and was significantly superior to treatments B_1N_0, B_0N_2, B_0N_1 and B_0N_0. Also treatment B_0N_2 recorded a significant response over treatment B_0N_1 which in turn was superior to B_0N_0. Table IV reveals that green manuring in conjunction with superphosphate and ammonium sulphate produced the greatest response, i.e. 42·05 per cent over control.

Results of observations on height of shoot before harvest are presented in Table V. It is evident from Table V that green manuring significantly increased the height of the shoot. Also, the addition of phosphate to green manure further produced significant increases over green manure alone. Sulphate of ammonia also significantly increased the height of the shoot. However, the differences due to 40 lb. N and 20 lb. N were slight and not significant.

Treatments B_2N_2 and B_2N_1 were found to be significantly superior to treatment B_1N_0. Also treatments B_0N_2 and B_0N_1 proved to be significantly superior to treatment B_0N_0. Thus, it is clear that like effective tillers, green manuring in conjunction with superphosphate and ammonium sulphate produced the greatest height. The increase amounted to 12·6 per cent more than the control.

Data on the yield of paddy per acre are given in Tables VII and VIII.

TABLE V. EFFECTS OF GREEN MANURING AND AMMONIUM SULPHATE ON HEIGHT OF SHOOT

Treatment	Height (cm.)				Per cent increase over B_0
	1952	1953	1954	Mean	
B_2	100·8	112·1	108·8	107·3	5·92
B_1	99·6	109·3	107·7	105·5	4·15
B_0	96·6	106·6	100·6	101·3	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·38	±0·75	±1·48	±0·61	..
C.D. at 5%	1·07	2·15	4·20	1·73	Per cent increase over N_0
N_2	100·3	110·9	107·6	106·3	4·01
N_1	99·0	110·4	107·4	105·6	3·33
N_0	97·8	106·3	102·0	102·2	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·38	±0·75	±1·48	±0·61	..
C.D. at 5%	1·07	2·15	4·20	1·73	..

TABLE VI. INTERACTION BETWEEN GREEN MANURING AND AMMONIUM SULPHATE

Treatment	Height of shoot (cm.)				Per cent increase over B_0N_0
	1952	1953	1954	Mean	
B_2N_2	101·6	113·6	108·7	108·1	12·6
B_2N_1	100·6	112·7	108·5	107·3	11·77
B_2N_0	100·1	110·1	109·3	106·5	10.94
B_1N_2	100·9	110·9	108·2	106·7	11·15
B_1N_1	99·6	109·8	108·3	105·9	10·31
B_1N_0	98·3	107·1	106·5	104·0	8·33
B_0N_2	98·0	108·2	105·9	104·1	8·44
B_0N_1	96·8	108·8	105·6	103·7	8·02
B_0N_0	95·0	102·7	90·3	96·0	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·66	±1·30	±2·56	±1·05	..
C.D. at 5%	1·88	3·71	7·31	3·00	..

TABLE VII. EFFECT OF GREEN MANURING AND AMMONIUM SULPHATE ON THE YIELD OF PADDY (MAUNDS PER ACRE)

Treatment	1952	1953	1954	Mean	Per cent increase over B_0
B_2	35·88	46·63	38·07	40·19	27·67
B_1	34·75	45·60	37·83	39·37	25·06
B_0	30·83	36·00	27·64	31·48	..
F-test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±0·84	±0·70	±1·27	±0·55	..
C.D. at 5%	2·40	2·00	3·66	1·57	Per cent increase over N_0
N_2	35·17	44·59	35·82	38·52	10·21
N_1	33·54	43·98	35·23	37·58	7·53
N_0	32·75	39·66	32·49	34·95	..
F-test	Not sig.	Sig.	Not sig.	Sig.	..
S. Em.	±0·84	±0·70	±1·27	±0·55	..
C.D. at 5%	..	2·00	..	1·57	..

Table VII reveals that every year, green manuring significantly increased the yield of paddy. Application of phosphate to green manure did not improve the yields of paddy significantly over green manure alone. The cumulative effect of phosphate as revealed in 1954 also was not significant. Sulphate of ammonia at both levels generally increased the yields although the differences in the first and third years were statistically not significant. Treatments N_2 and N_1 were at par with each other.

TABLE VIII. INTERACTION BETWEEN GREEN MANURING AND AMMONIUM SULPHATE

Treatment	Yield of paddy (md.)				Per cent increase over B_0N_0
	1952	1953	1954	Mean	
B_2N_2	37·89	46·47	38·12	40·82	52·43
B_2N_1	35·61	47·25	38·56	40·46	51·08
B_2N_0	34·22	46·14	37·53	39·31	46·79
B_1N_2	35·61	46·06	38·07	39·91	49·03
B_1N_1	33·97	46·55	37·83	39·44	47·27
B_1N_0	34·67	44·18	37·63	38·76	44·36
B_0N_2	32·10	41·20	31·21	34·83	30·08
B_0N_1	31·03	38·14	29·35	32·84	22·63
B_0N_0	29·35	28·67	22·34	26·78	..
F-test	Sig.	Sig.	Sig.	Sig.	..
S.Em.	±1·45	±1·21	±2·21	±0·95	..
C.D. at 5%	4·14	3·45	6·31	2·73	..

It is seen from Table VIII that in the first year all the green-manure treatments were at par among themselves although the treatment B_2N_2 produced the highest yield. The three nongreen-manure treatments did not differ among themselves significantly and recorded lower yields than green manure treatments. In the second year also, a similar trend was followed except that the sulphate of ammonia treatments B_0N_2 and B_0N_1 were significantly superior to treatment B_0N_0. In the third year, all the green-manure treatment combinations were significantly superior to non green-manure treatments. Also treatments B_0N_2 and B_0N_1 were significantly superior to B_0N_0 as in the previous year. The mean data for three years exhibit the same trend as in the third year. Table VIII clearly shows that with successive crops of paddy, the cumulative effect of green manure became conspicuous as the increases over 'control' progressively improved. Also the effect of ammonium sulphate increased over 'control' in later years.

TABLE IX. RESPONSE OF PADDY TO GREEN MANURING

Treatment	Response (in lb.) of grain per lb. of N			
	1952	1953	1954	Mean
B_2 Green manure plus 60 lb. P_2O_5	5·97	12·58	12·34	10·31
B_1 Green manure alone	4·77	11·68	12·39	9·60

It is observed from Table IX that the overall response to green manuring in the first year was small due to the high fertility built up by the berseem crop in the rotation. In the subsequent two years, with declining productivity of the land higher response to green manuring was obtained. Application of phosphate to green manure crop did not produce appreciable response.

TABLE X. RESPONSE OF PADDY TO AMMONIUM SULPHATE

Treatment	Response (in lb.) of grain per lb. of N			
	1952	1953	1954	Mean
N_2 40 lb. N	4·98	10·14	6·85	7·35
N_1 20 lb. N	3·25	17·78	11·28	10·82

Like green manuring the overall response to ammonium sulphate in the first year was not appreciable but improved considerably afterwards. Higher response was obtained with 20 lb. N than with 40 lb. N dose. A greater response per pound of nitrogen was recorded in 1953 than 1954 due to more favourble weather conditions prevailing during that year.

The response as in case of main treatments was the lowest in the first year. In the last two years,viz. 1953 and 1954, the response of paddy per pound of nitrogen was the greatest in case of 20 lb. N followed by 40 lb. N in the form of ammonium

sulphate. The next in order was green manuring. All other combinations having higher doses of N showed lower efficiency of nitrogen per pound of N. This seems to be due to the operation of the ' Law of Diminishing Returns ' as the response for every additional dose of nitrogen in the other combinations began to decline. Thus minimum response per pound of nitrogen was obtained by B_2N_2 treatment with highest level of nitrogen.

TABLE XI. RESPONSE OF PADDY DUE TO INTERACTION BETWEEN GREEN MANURING AND AMMONIUM SULPHATE

Treatment	Response (in lb.) of grain per lb. of N			
	1952	1953	1954	Mean
B_2N_2–109·56 lb. N	6·42	13·37	11·58	10·55
B_2N_1– 89·56 „ „	5·75	17·07	14·91	12·57
B_2N_0– 69·56 „ „	5·76	20·67	17·97	14·82
B_1N_2–107·67 „ „	4·78	13·29	12·02	12·19
B_1N_1– 87·67 „ „	4·34	16·78	14·54	11·88
B_1N_0– 67·67 „ „	6·47	18·86	18·60	14·45
B_0N_2– 40·00 „ „	5·66	25·78	18·25	16·56
B_0N_1– 20·00 „ „	6·91	38·97	28·85	24·94

TABLE XII. EFFECTS OF GREEN MANURING AND AMMONIUM SULPHATE ON THE YIELD OF STRAW (MAUNDS PER ACRE)

Treatment	Yield of straw				Per cent increase over B_0
	1952	1953	1954	Mean	
B_2	64·96	59·10	54·49	59·51	23·01
B_1	56·94	57·50	50·23	54·88	13·44
B_0	51·60	49·00	44·54	48·38	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±1·86	±1·52	±1·83	±1·01	..
C.D. at 5%.	5·32	4·35	5·23	2·89	Per cent increase over N_0
N_2	60·52	60·70	53·95	58·39	17·94
N_1	60·04	55·20	49·34	54·86	10·80
N_0	52·96	49·60	45·96	49·51	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±1·86	±1·52	±1·83	±1·01	..
C.D. at 5%.	5·32	4·35	5·23	2·89	..

The results indicate that green manuring produced significantly higher yields of straw per acre than no green-manuring. The effect of phosphate on green manuring was also favourably maintained. Sulphate of ammonia treatments, viz. N_2 and N_1 treatments proved significantly superior to N_0 treatment. Between N_2 and N_1 treatments, N_2 recorded a higher increase than N_1 treatment. Thus green manuring, superphosphate and sulphate of ammonia each contributed in increasing the yields of straw.

TABLE XIII. INTERACTION BETWEEN GREEN MANURING AND AMMONIUM SULPHATE

Treatment	Yield of straw (in md.)				Per cent increase over B_0N_0
	1952	1953	1954	Mean	
B_2N_2	68·75	62·82	56·69	62·77	48·78
B_2N_1	68·21	60·52	53·80	60·86	44·25
B_2N_0	57·97	53·90	52·92	54·93	30·20
B_1N_2	60·17	62·33	54·98	59·14	40·18
B_1N_1	56·50	56·35	49·25	54·05	28·11
B_1N_0	54·19	53·75	46·45	51·45	21·95
B_0N_2	52·63	57·09	50·23	53·31	26·36
B_0N_1	55·42	48·85	44·93	49·74	17·90
B_0N_0	46·75	41·24	38·56	42·19	..
F–test	Sig.	Sig.	Sig.	Sig.	..
S. Em.	±3·22	±2·63	±3·17	±1·75	..
C.D. at 5%	9·18	7·48	9·07	5·00	..

The data in Table XIII show that straw yields were considerably higher with the application of green manure in conjunction with both N and P fertilizers. The combinations B_2N_2 and B_2N_1 produced the maximum quantities of straw. With regard to non green-manure treatments, both N_2 and N_1 treatments, particularly the former also increased the yields over 'Control'.

DISCUSSION

In the present investigation an attempt has been made to examine the effects of green manuring (with and without phosphate) in conjunction with ammonium sulphate, on the yields of paddy.

Studies on *dhaincha* (*Sesbania aculeata*) crop showed that the application of 60 lb. P_2O_5 in the form of superphosphate did not significantly influence the weight of green matter per acre. The lack of response to superphosphate by the leguminous *dhaincha* crop seems to be due to fairly high level of soil fertility, particularly in case of nitrogen and total and available phosphoric acid. Similar results have also been reviewed by Sen and Rao [1952] who reported that leguminous green-manure crops,

viz. sannhemp (*Crotalaria juncea*), cowpea (*Vigna catiang*) and *dhaincha* responded well to phosphatic manuring in Bihar and Mysore where the soils are deficient in phosphate but failed to record significant response at Kanpur which may be attributed to high reserve of available phosphate in the soil. Thus, the response of legumes to phosphates in India has been conspicuous in soils poor in available phosphoric acid.

Application of superphosphate to *dhaincha* also did not increase the nitrogen content of the green matter. This type of response has been reported by Ghosh [1954] who found that addition of 80 lb. P_2O_5 to sannhemp green-manure crop did not change its nitrogen per cent composition.

With regard to paddy, the three years data reveal that the overall effect of green manure treatments B_2 and B_1 produced significantly higher yields than non green-manure treatments. The increases in grain yield due to the green manuring are attributed to more number of effective tillers. These findings agree with the observations of earlier workers, namely Allan [1915], Sethi [1928], Churikov [1939], Ramiah and Sahasrabudhe [1947], Pandya [1952-53], Fellner [1953], Raheja [1953] and Abichandani [1953].

Regarding the effect of phosphates on green manuring, Allan [1915], Taylor and Ghosh [1923], Arnold [1931], Bal [1937], Viswanath [1937], Parr and Bose [1944, '45 & '47], Mukherjee and Agarwal [1950], and Mirchandani and Khan [1953] have advocated the application of phosphate to green-manure crops. The results obtained by green manuring in conjunction with phosphate in this particular experiment show that the addition of phosphate to green-manure crop did not produce significant increases over green manuring alone. This is chiefly due to the fact that the soil where this experiment was conducted had a fairly high content of available phosphoric acid. This appears to be the main cause for obscuring the effect of phosphate on green manuring. Such a behaviour can also be ascribed to the lack of response in the production of green matter itself due to phosphate manuring.

With regard to the effect of green manuring in conjunction with ammonium sulphate, the combination B_2N_2 gave the best response. This is also seen from the study of effective tillers. However, this combination has not been found to be significantly superior to other green-manure treatments. Harrison and Aiyer [1916], Ramiah and Sahasrabudhe [1947], and Nair [1953] and Anonymous [1953] have recommended green manures in conjunction with ammonium sulphate for increased paddy yields. The findings of the present experiment do not agree with the above views, possibly due to original fairly high nitrogen content of the soil and appreciable dozes of nitrogen applied in the form of green manure itself. This kind of presumption corroborates with the findings of Ramiah and Abraham [1952] who stated that when green manures and cakes supplied the optimum amount of nitrogen, further addition of sulphate of ammonia did not increase the yields. It would, thus, be seen that the application of ammonium sulphate in addition to green manuring has a limited advantage when there is already an optimum supply of nitrogen from the green manuring source and that the soils are fairly fertile.

Among the non-green manure treatments, the differences in the first year although in favour of N_2 and N_1 treatments, were not significant. In the second and third years, both treatments, N_2 and N_1, were significantly superior to N_0 treatment.

The study on the formation of effective tillers also showed that treatments N_2 and N_1 were at par with N_0 treatment in the first year but significantly superior to it in the last two years. The data, thus, indicate that like green manuring, sulphate of ammonia also increased the number of effective tillers which contributed in increasing the yield of paddy.

In the first year, the crop followed on a land where fertility had been built up by continuous paddy-berseem rotation for some years and, therefore, the effect of sulphate of ammonia was masked. The beneficial effect of berseem in building up soil fertility has been reported by Khan and Bhatnagar [1945] who found at Karnal that ammonium sulphate at 40 lb. N increased the yields of paddy in a paddy-oat or paddy-fallow rotation but proved superfluous in a paddy-berseem rotation. Similar results have also been mentioned by Ganguly and Relwani [1954]. Subsequently, when the effect of past built-up fertility was partially reduced by growing paddy crops without berseem in the rotation, the effect of ammonium sulphate was observed. However, 40 lb. N dose did not produce significantly superior yields over 20 lb. N application. Thus, ammonium sulphate showed a restricted advantage as a fertilizer for paddy crop where paddy-berseem rotation was followed. Later on, with falling fertility the effect was more pronounced.

Response of paddy per pound of nitrogen was lowest in the first year. This was due to the initial high level of productivity of the land. Later on response to both green manuring as well as ammonium sulphate increased with declining fertility due to exclusion of leguminous berseem crop from rotation. There was a progressive improvement in the yield of paddy with every additional dose of nitrogen as the increase over 'no manure' was 22·63 per cent for 20 lb. N dose and steadily rose to 52·43 per cent for 109·56 lb. N application. However, the response per unit of nitrogen was the greatest with the minimum dose of nitrogen, viz. 24·94 lb. paddy grain per pound of nitrogen for 20 lb. N dose in the form of ammonium sulphate, and declined over the whole range with the minimum response of 10·55 lb. of paddy grain per pound of nitrogen in the case of B_2N_2 treatment which supplied 109·5 lb. nitrogen. This is in accordance with the Law of Diminishing Returns resulting in lesser response for every additional dose of nitrogen till no more increase is obtained with further supplements of nitrogen.

As regards straw yields, the same treatments, viz. green manuring, superphosphate, sulphate of ammonia and their combinations which produced greater height of the shoot also maintained higher yields of straw.

SUMMARY

The soil of the experimental site was fairly rich in nitrogen and phosphoric acid. Application of superphosphate at 60 lb. P_2O_5 to green manure *dhaincha* (*Sesbania aculeata*) crop did not significantly increase the weight of green matter per acre over green manure alone. The nitrogen content of *dhaincha* shoot also showed negligible differences under the two treatments.

The overall effect of green-manure treatments, with or without phosphate application, produced significantly higher yields of paddy than no green-manure treatments. However, the differences between the two green-manure treatments were not

significant. The number of effective tillers produced was also significantly greater in green manure than no green-manure treatments.

Although green-manuring in conjunction with superphosphate and ammonium sulphate did not produce significantly greater yields than green manuring alone, the combination with 60 lb. P_2O_5 and 40 lb. N produced the maximum yield.

The overall effect of nitrogen in the form of ammonium sulphate on the yield of paddy was small in the beginning but increased significantly afterwards; 40 lb. N dose was generally at par with 20 lb. N application.

Both green manuring and ammonium sulphate as well as their combinations produced significantly greater number of effective tillers than 'Control'. This contributed in increasing the yield of paddy under these treatments. Phosphate applied to green manure did not influence the formation of effective tillers appreciably.

Response of paddy per pound of nitrogen was the minimum in the first year, but increased in the subsequent years. There was a steady increase in the yield of paddy with higher dose of nitrogen but the response per unit of nitrogen was maximum with 20 lb. N application in the form of ammonium sulphate.

Green manuring, ammonium sulphate, superphosphate and their different combinations significantly increased the yield of straw over 'Control'.

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SEED PLACEMENT OF FERTILIZER IN RICE

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Seed placement of fertilizer by soaking seed in nutrient solutions was advocated by Gusev [1940] and Roberts [1948], as a means of increasing grain yield of cereals. Roberts (*loc. cit.*) tried various concentrations of different potassium and ammonium phosphates and reported 11 to 48·6 per cent increase in yield of barley and 46 per cent increase in yield of oats by soaking seed prior to sowing, in molar concentrations of K_2HPO_4 and K_3PO_4 respectively. With wheat also, she obtained significant increase in grain yield by soaking seed in molar and 5 per cent potassium dihydrogen phosphate solution. Seed soaking trials with rice have also been reported. Narayanan and Gopalakrishnan [1949] obtained 21·1 and 38·8 per cent increase in yield of rice grain, in pot-culture trials, with seed soaked in 10 and 20 per cent tri-potassium phosphate respectively. Rhind *et al.* [1950] also reported 20·3, 18·8 and 36·2 per cent increase in grain yield under pot-culture conditions with 5, 10 and 20 per cent di-potassium hydrogen phosphate respectively. Both these authors, however, could not get any yield increase with soaked seed sown under field conditions. In view of earlier success, reported by Roberts (*loc. cit.*) with cereals, work on soaking of rice seed in nutrient solution, to study its effect on yield of grain had been started at the Central Rice Research Institute, Cuttack in 1948 and Abichandani and Ramiah [1951] had summarised some preliminary observations using a number of nutrient solutions. They reported favourable yield increase with solutions of di- and tri-potassium phosphates, under field conditions. Further field trials were, therefore, continued and the results of these investigations are summarised in this article.

MATERIAL AND METHODS

Chemicals for seed soaking: A number of phosphate compounds like mono-, di- and tri-potassium phosphates, mono- and di-ammonium and sodium phosphates were tried in preliminary trials in 1949-51. In addition, nitrogenous fertilizers like ammonium sulphate and ammonium nitrate were also tried. All chemicals were tried in three different concentrations, twice molar (2M), molar (M) and half molar (M/2). Besides this, treatment with cowdung paste, soaking seed in cattle urine and tap water were also investigated. In trials during later years, only two promising phosphate chemicals, the di- and tri-potassium phosphates at 10 and 20 per cent concentrations were used. These concentrations roughly correspond with M/2 and M concentrations, used in earlier trials. These changes were done because the various molar concentrations used in earlier years did not differ significantly in their effect on germination and on grain yield. Besides this, treatment with concentrated solution of ammonium sulphate (1:2 in water), with little boiled starch added, was also included, to study the manurial effect of a thin visible coat of nitrogenous fertilizer

adhering to the seed surface. It had been earlier observed that treatment of rice seed in dilute solution of ammonium sulphate, was comparatively easily washed off with copious irrigation or heavy down-pour of rain soon after sowing.

Method of soaking: Soaking procedure was same as recommended by Roberts [1948]. The quantity of solution used for soaking was such as could be easily absorbed by the seed in 24 hours. Rate of imbibition of water by rice seed was determined for a few varieties of rice by soaking seed in excess water. The seeds took up 22-24 per cent of the weight of water in the first 12 hours and about 5-7 per cent in next 12 hours of soaking period respectively. Rice seed for experimental trials was, therefore, soaked in one-third its weight of solution for 24 hours. Soaking was done in air-tight containers, rotated continuously for 12 hours on a shaking machine and thereafter, for next 12 hours, an occasional shaking for ten to 15 minutes at an interval of every two to three hours was given to effect uniform mixing. By this method, nearly all the solution was absorbed by the seed. Soaking of seed in 1:2 solution of ammonium sulphate in water was, however, done for six and 24 hours respectively. The soaked seed was then sun dried and stored in closed containers, for sowing.

Field trials: Treated seed were sown in replicated trials and in early experiments, conducted during 1949-52. All treatments were tried with and without a basal dressing of 20 lb. nitrogen per acre, given as ammonium sulphate. As no interaction was observed between chemical treatments or their concentrations and the nitrogen fertilizer, all later trials were conducted at a uniform basal level of 20 lb. nitrogen per acre.

In earlier trials during 1949-52, treated seeds were sown in small plots in lines, sown continuously without leaving any non-experimental line or pathway in between treatments. This was done because there was no danger of lateral movement of seed placed fertilizer, the treatments having been given to seed prior to sowing. Non-experimental borders were, however, provided on the outs of the plots at two ends of each block. At the time of harvest, therefore, all lines were harvested, leaving one foot borders along two ends of the plot, lengthwise.

Rice varieties tried and seed-rate used in different trials were as follows:

1949-50: Variety T. 608 (early duration) was tried and experiment was laid out in four replications in an upland sandy clay loam soil. Seed was sown in small plots in lines nine inches apart, with seed-rate of 45 lb. per acre for all treatments. To get uniform stand in all lines, quantity of seed for each plot was divided in equal parts, depending on number of lines per plot and sown uniformly in each line. Net harvest plot size was 5 feet 3 inches $\times$ 10 feet.

1950-51: Same variety T. 608 was used and trial was again laid out in four replications on the same land as in the previous year. As chemical treatments in previous years had generally given depressed germination, seed was, therefore, dibbled in lines which were nine inches apart. Dibbling was done by putting three to four seeds per hole at a distance of four inches apart in each line. Crop was later thinned, one month after germination, to maintain a uniform stand in all plots. Net harvest plot size was 4 feet 6 inches $\times$ 10 feet.

1951-52: Three varieties Co. 13 (early duration), T. 1145 and T. 141 (both medium duration) were tried in a medium land clay loam soil. Early duration was

changed over from T. 608 used in previous years to Co. 13, because the latter was higher yielding and more suited for growth under medium land conditions. Four replications were laid out and seed was sown in lines as in year 1949-50. Experiment was laid out in split plot design with varieties in the main split. Seed-rate used was 30 lb. per acre for untreated control and 10 per cent more (33 lb./acre) for treated seeds to compensate for the depressed germination observed with the latter. Net plot size was 6 feet 9 inches × 17 feet.

Besides this, bulk trials on the Institute Farm area and on the cultivators' fields round about the Institute area were also laid out. In these trials, rice variety T. 1145 was used and the seed was sown broadcast as is commonly practised by the cultivators in the area. Seed-rate used was 30 lb. for untreated control and 10 per cent more for treated seeds. Bulk trial at the Institute area was laid out in eight replications with gross and net plot size as 11 ft. × 44 ft. and 9ft. × 42 ft. respectively. Trials on cultivators' fields were laid out at nine locations and at each place, a field of about 4-6 cents in area was divided into two equal parts and sown with treated and untreated seeds respectively. All subsequent operations in these fields were done by the cultivators as usual. At the time of harvest, one random sample of 16·5 ft. × 16·5 ft. was taken from different treatments at each location and grain yield recorded.

1952-53: Variety Co. 13 in upland sandy clay loam and variety T. 141 in a medium land clay loam soil were used and seed was broadcast as commonly practised by the cultivators in the area. Seed-rate for treated and untreated seed was same as in 1951-52. Six replications were laid out for each of the trials with gross and net plot sizes as follows:

Variety	*Gross plot size* (feet)	*Net plot size* (feet)
Co. 13	15×42	13×40
T. 141	20×41	18×39

Effect of seed soaking on seed germination: Soaking of seed in different chemicals generally depressed germination. During 1949-50, percentage germination of seed under field condition, 15 days after sowing, was estimated by counting germinated seeds in two lines out of six in each plot. It was seen that germination of chemically treated seed was significantly depressed by 10 to 15 per cent. There was, however, no difference in germination between seeds treated at different concentrations, i. e. 2M, M and M/2, of the same chemical, nor was there any interaction between chemical treatments and basal nitrogen dressing. Cowdung paste also depressed germination considerably. Germination, average of three concentrations and nitrogen treatments is given in Table I.

It was also seen that chemical treatments generally delayed germination of the seed by two to three days as compared to control. Germinated seedlings, however, put up sufficient growth in next eight to ten days and there appeared no apparent difference in the growth of seedlings in treated and untreated plots.

Di-ammonium phosphate and cattle urine treatments, which were included in trials during 1950-51, also depressed germination, particularly former at 2M and M concentrations. In preliminary germination trials, during the year, treatment with superphosphate of lime and ammonium phosphate both fertilizer grade, were also tried out but because of adverse effects on germination, these were not included in field trials. During this year (1950-51), seeds were dibbled in each line by putting three to four seeds per hole at a distance of four inches and later one month after germination, crop was thinned to keep a uniform stand in all plots.

TABLE I. GERMINATION COUNT WITH DIFFERENT CHEMICAL TREATMENTS

(average of three concentrations—2M, M and M/2 and nitrogen level N_o and N_2O)

Chemical treatment	Germination count (2 lines)	Germination index
KH_2PO_4	316	90
K_2HPO_4	323	92
K_3PO_4	320	91
$NH_4H_2PO_4$	314	89
NaH_2PO_4	324	92
Na_2HPO_4	312	89
$(NH_4)_2SO_4$	321	91
NH_4NO_3	299	85
Cowdung paste	267	76
Water soaked	327	93
Untreated control	352	100
S.E. of mean	9	
C.D. at 5%	26	

During 1951-52, when three varieties Co. 13, T. 1145 and T. 141 were tried and seed-rate with chemically treated seeds was increased by 10 per cent, germination count in field plots was taken 21 days after sowing. Stand in all treatments was found to be fairly uniform except with water-soaked seeds of variety Co. 13 and T. 1145. These varieties were earlier seen to have partly germinated on water soaking and had consequently lost a part of their viability on drying, so that germination was 24 and 73 per cent respectively as compared to control (100). Results of germination count are given in Table II.

It was also observed that the treated seed had to be thoroughly air dried otherwise germination was affected considerably during storage. Seeds, properly sun dried immediately after treatment, were stored for about 40-50 days without any further loss in viability.

RESULTS AND DISCUSSION

Yield data with various treatments for trials during 1949-50 and 1950-51 are shown in Table III. No significant interaction between chemical treatment and nitrogen fertilizer was observed, and the concentration of various chemicals were not significantly different; hence, yield per acre is given as average of three concentrations

TABLE II. GERMINATION COUNT OF THREE RICE VARIETIES WITH DIFFERENT CHEMICAL TREATMENTS

Chemical treatments	Germination count per two lines		
	Co. 13	T. 1145	T. 141
$K_2 HPO_4$ (10 per cent)	205	197	137
$K_2 HPO_4$ (20 per cent)	201	182	121
$K_3 PO_4$ (10 per cent)	212	200	118
$K_3 PO_4$ (20 per cent)	192	182	115
$(NH_4)_2 SO_4$ (1:2 in water; 24 hr. treatment)	190	210	105
$(NH_4)_2 SO_4$ (1:2 in water; 6 hr. treatment)	202	213	118
Water soaked	50	141	105
Untreated control	210	193	120
S.E. of mean	8	8	8
C.D. at 5%	22	22	22

TABLE III. INFLUENCE OF SEED SOAKING ON YIELD OF RICE

(Mean yield of grain, lb. per acre and yield index—average of concentrations and nitrogen levels)

Chemical treatments	1949–50		1950–51	
	Yield(lb./acre)	Yield index	Yield(lb./acre)	Yield index
$KH_2 PO_4$	896	108·0	768	102·9
$K_2 HPO_4$	954*	114·9	875*	117·3
$K_3 PO_4$	929*	111·9	825	110·6
$NH_4 H_2 PO_4$	904*	108·9	822	110·2
$(NH_4)_2 HPO_4$ (M/2)	—	—	838	112·3
$NaH_2 PO_4$	946*	113·9	769	103·1
$Na_2 HPO_4$	896	107·9	840	112·6
$(NH_4)_2 SO_4$	929*	111·9	720	96·5
$NH_4 NO_3$	921*	110·9	809	108·4
Cowdung paste	855	103·0	—	—
Cattle urine	—	—	299	40·1
Water soaked	896	107·9	817	109·5
Untreated control	830	100·0	746	100·0
S.E. of mean	25	—	39	—
C.D. at 5%	70	—	110	—

*Significant at 5 per cent level.

(2M, M and M/2) and nitrogen levels. It is seen that during 1949-50, chemical treatments di- and tri- potassium phosphates, mono-ammonium phosphate, mono-sodium phosphate, ammonium sulphate and ammonium nitrate, all gave significantly higher yield than control. Chemical treatments with di-potassium phosphate gave maximum yield increase of 14·9 per cent over control. In the next year (1950-51) also, a similar trend of yield increase with different chemicals was observed and again, treatment with di-potassium phosphate gave highest yield increase of 17·3 per cent over control. Some other treatments, which had shown promise in the previous year, also gave higher yield than control, but the increases were not significant. Treatment with ammonium sulphate, however, failed to register any yield increase during the second year of trial.

In trials conducted with three rice varieties, Co. 13, T. 1145 and T. 141 during 1951-52 also, no interaction between chemical treatments and nitrogen fertilizer was observed. In this trial (Table IV), all chemical treatments generally gave higher yield of grain than untreated control, but yield increase with treatments of 10 and 20 per cent di-potassium phosphate, 20 per cent tri-potassium phosphate and ammonium sulphate (1:2 in water soaked for six hours) were significantly superior to control, only in the case of T. 141. By taking average yield of all the three varieties, however, significant yield increases were obtained with 10 and 20 per cent di-potassium phosphate and ammonium sulphate treatments only. The results also showed an indication of difference in the varietal response to chemical treatments.

TABLE IV. INFLUENCE OF SEED SOAKING ON GRAIN YIELD OF RICE
(Mean yield of grain, lb. per acre—average of nitrogen and no nitrogen plots—1951-52)

Chemical treatments	Variety Co. 13	Variety T. 1145	Variety T. 141	Mean	Yield index
K_2HPO_4 (10 per cent)	1332	2295	2399*	1997*	109·6
K_2HPO_4 (20 per cent)	1291	2300	2414*	2002*	109·8
K_3PO_4 (10 per cent)	1215	2103	2338	1885	103·5
K_3PO_4 (20 per cent)	1207	2240	2380*	1942	106·6
$(NH_4)_2SO_4$ (1:2 in water; 24 hr. soaked)	1287	2240	2312	1946*	106·8
$(NH_4)_2SO_4$ (1:2 in water; 6 hr. soaked)	1257	2251	2376*	1961*	107·6
Water soaked	717 (Poor germination)	2050	2319	1695	93·0
Untreated control	1219	2111	2137	1822	100·0
S.E. of mean	74	74	74	43	
C.D. at 5%	207	207	207	121	

*Significant at 5 per cent

In cultivators' field trials (Table V) conducted during the same year with variety T. 1145, 20 per cent, di-potassium phosphate treatment gave significantly

higher yield increase of 8·7 per cent over control; the response due to treatment, however, varied considerably from place to place. In bulk trials with variety T. 1145, conducted on the farm area (Table V), yield increase of 3·7 per cent over control, obtained with 20 per cent di-potassium phosphate was not significant, and only ammonium sulphate treatments gave significant yield increase of 7·5 per cent over control.

TABLE V. INFLUENCE OF SEED SOAKING ON GRAIN YIELD OF RICE (MEAN YIELD LB./ACRE—1951-52)

Chemical treatments	Variety T. 1145	
	Cultivators' field trials	Institute area bulk trial
$K_2 HPO_4$ (20 per cent)	1879* (108·7)	2826 (103·9)
$(NH_4)_2 SO_4$ (1:2 in water)	—	2927* (107·6)
Untreated control	1728 (100·0)	2721 (100·0)
S.E. of mean	44	54
C.D. at 5%	145	158

*Significant at 5 per cent level.

Trials in 1952-53, conducted with two varieties at different locations in the farm area also showed the superiority of di-potassium phosphate treatment over control (Table VI). Significant yield increases of over 200 lb. per acre (7·7 per cent over control), due to treatment with 10 per cent di-potassium phosphate was once again obtained with variety T. 141. Yield increase with Co. 13 for the same treatment was, however, very much less and not significantly superior. Ammonium sulphate treatment during this year, however, failed to register any yield increase.

TABLE VI. INFLUENCE OF SEED SOAKING ON GRAIN YIELD OF RICE (MEAN YIELD LB./ACRE—1952-53)

Chemical treatment	Variety Co. 13	Variety T. 141
$K_2 HPO_4$ (10 per cent)	998 (109·3)	2785* (107·7)
$(NH_4)_2 SO_4$ (1:2 in water)	937 (102·6)	2604 (100·7)
Untreated control	913 (100·0)	2587 (100·0)
S.E. of mean	90	62
C.D. at 5%	225	195

*Significant at 5 per cent level.

Results generally indicate a beneficial effect of seed soaking in nutrient solutions, particularly in 10 and 20 per cent di-potassium phosphate solution in water, prior to sowing, giving yield increases ranging from 8-15 per cent over control, in different trials. These findings are in agreement with those, earlier reported by Narayanan and Gopalakrishnan [1949] and Rhind *et al.* [1950], regarding rice. It appears that phosphate placed along with the seed in this manner gives beneficial effect on grain yield.

Soaking of seed in 1:2 ammonium sulphate in water also showed promise in certain trials, but response varied considerably from year to year. It was generally observed that response with this treatment was less in trials, where there was not sufficient moisture in the soil at sowing and particularly if the rainfall was delayed by three to four days after sowing. In such cases, poor and patchy germination of crop was observed with ammonium sulphate treated seeds. This was probably because high concentration of fertilizer, immediately round-about the germinating seed, i.e. at very low moisture levels, impaired seed germination.

SUMMARY

Method of seed placement of fertilizer, by soaking seed in nutrient solutions, prior to sowing, as a means of increasing yield of rice crop, has been described. Soaking of seed has been tried in a number of nutrient solutions like potassium, sodium and ammonium phosphates and also ammonium sulphate and ammonium nitrate, at different concentrations. Treatment with potassium, phosphate (dibasic) at 10 and 20 per cent concentrations, in water, is found to increase yield of rice by 8-15 per cent over control, in different field trials.

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FERTILIZER EXPERIMENT ON MAIZE

I. DIRECT EFFECT OF NITROGENOUS, PHOSPHATIC AND POTASSIC FERTILIZERS AND THEIR COMBINATIONS ON YIELD

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Numerous workers have related maize yields to the nitrogen content of soils and have found nitrogen to be the main limiting factor in its production. Salter [1946] found that in Ohio over a 33-year period continuous cropping with maize on untreated plots led to a decline in both nitrogen content of the soil and maize yield. Jenny [1930] found that with 12 different Missouri soils under similar climatic environment, average corn yields on unfertilized plots were closely related with soil nitrogen content. Sufficient experimental evidence has accumulated to show that corn yields can be boosted up by heavy applications of nitrogenous fertilizers. Increases in yield have been obtained corresponding to an increase in the dose of nitrogen as is evident from the published work of Crowther *et al.* [1937], Fitts [1945], McVickar *et al.* [1947], Paterson *et al.* [1949], Harper *et al.* [1949], Krantz [1949], and Krantz and Chandler [1951].

The presence in soils of sufficient quantities of available P_2O_5 for normal plant development and grain yield of maize has been stressed by Richey [1933], De Turk [1940], Gericke [1942] and Lewis [1941]. Rather and Tyson [1943] have emphasized the importance of phosphate resulting in early maturity leading to high yields. Such results were observed earlier by Olson [1927], Salter [1931], and Olson and Walster [1934] also.

Response to potash depends largely on the potash level of the soil. Mooers [1933] found that potash as a fertilizer for maize was without any value.

Practically the whole work cited above relates to foreign workers as information on the manurial aspect of maize cultivation in India is scanty. Vaidyanathan [1933] reported high response to nitrogenous fertilization from Kanke, Sepaya and Banka farms in Bihar on poor, good loamy and calcareous light loamy soils respectively. Similar results were obtained with organic manures at Madras, Kanpur and Nagpur. But most of these trials were either unreplicated or with insufficient number of replications. An experiment on heavy soil showed in Bihar [1937-40] that nitrogen alone gave the best response and phosphate rather depressed it. High doses of phosphate, however, in combination with high doses of nitrogen showed better results. A 100 per cent increase in yield was obtained in Punjab (1949-50) when ammonium sulphate at 100 lb. nitrogen was applied to the crop per acre.

This work was started in order to study the effect of nitrogen, phosphate and potash at different levels and ratios on (i) yield of maize grain and stover, and (ii) residual effects on wheat of fertilizers applied to maize in a cereal rotation.

In this article, the yield results of maize and economics of fertilization are presented.

MATERIAL AND METHODS

The experiment was conducted in plot Top Block 3-c of the Agronomy Farm at the Indian Agricultural Research Institute, New Delhi during the years 1949-53. The soil was sandy loam. The physical and chemical characteristics of the soil are given in Table I.

TABLE I. PHYSICAL AND CHEMICAL COMPOSITION OF SOIL

Depth of sample (inches)	(%) Clay	(%) Silt	(%) Fine sand	(%) Coarse sand
0– 6	9·40	14·60	71·86	2·08
6–12	8·20	16·56	71·92	2·44
12–18	8·80	16·40	71·43	2·01

	pH	*C* (%)	*N* (%)	*C/N*	(%) *Available* P_2O_5	(1%) *Citric acid* K_2O
0– 6	7·4	0·403	0·066	7·1	0·021	0·015
6–12	7·4	0·400	0·059	7·9	0·021	0·016
12–18	7·3	0·390	0·056	8·1	0·020	0·013

The field was lying fallow for five seasons ($2\frac{1}{2}$ years) prior to *rabi* 1948-49. In *rabi* 1948-49, it was under a general crop of *shaftal* (*Trifolium resupinatum*) to which fertilizers were not applied. The sequence of crops followed in this experiment was:

	Kharif	*Rabi*
1949–50	Maize	Fallow
1950–51	Maize	Wheat (residual)
1951–52	Maize	Wheat (,,)
1952–53	Maize	Wheat (,,)
1953–54	Maize	Wheat (,,)

The varieties of maize and wheat grown in the trial were Yellow No. 2 and N.P. 710 respectively.

The fertilizer treatments were:

Nitrogen	N_0	No nitrogen
	N_1	40 lb. nitrogen per acre as ammonium sulphate
	N_2	80 lb. nitrogen per acre as ammonium sulphate
Phosphate	P_0	No phosphate
	P_1	40 lb. P_2O_5 per acre as triple superphosphate
	P_2	80 lb. P_2O_5 per acre as triple superphosphate
Potash	K_0	No potash
	K_1	60 lb. K_2O per acre as potassium sulphate

The fertilizers were applied by placement to the maize crop, every year, by means of a ' horse hoe ' equipped with three iron tubes each with a funnel at the top.

The layout was $3\times3\times2$ confounded design in two replications each having three blocks of six plots. Interactions $N\times P$ and $N\times P\times K$ were partially confounded with blocks. Net size of each plot was 37 ft.$\times$19 ft.=1/62 acre.

Seeds were dropped through the central tube and the other two tubes were used to place the fertilizers simultaneously in two side bands, 2·5 inches away and one inch below the seed row. The depth at which the seed was dropped was about two to 2·5 inches. Maize was thinned when the crop was about six inches high, keeping a distance of nine to 12 inches between plants in the rows. Earthing up of the crop was done twice. The crop was harvested 93 days, 94 days, 97 days, 97 days and 95 days after sowing during the years 1949, 1950, 1951, 1952 and 1953 respectively. During 1949 and 1950, the crop matured on rainfall only, which was well distributed during the crop season whereas four irrigations were necessary to mature the crop in 1951. During 1952, monsoon rains failed during the month of September and as a result of great demand for irrigation for other *kharif* crops only two irrigations could be given to maize. This lack of irrigation water in 1952 depressed the yield of maize crop, in general.

The main weather features were characterised by a total failure of rainfall in September, 1952 coupled with a slight rise in maximum temperature, heavy fall in minimum temperature and relative humidity percentage as compared to the corresponding period of years 1949, 1950 and 1951.

Yield results: Yield results of maize cobs, grain and stalk as affected by different levels of nitrogen, phosphate and potash are presented in Tables II, III and IV.

TABLE II. YIELD OF MAIZE COBS, GRAIN AND STALK IN MAUNDS PER ACRE DUE TO NITROGEN

Year	Grain, cobs and stalk	0 lb. N	40 lb. N	80 lb. N	S.E. of mean ±	C.D. at 5%
1949	Cobs	34·50	41·00	41·30	0·71	2·16
	Grain	26·17	31·85	31·78	1·39	4·26
	Stalk	49·07	58·67	60·30	2·07	6·31
1950	Cobs	23·65	33·07	35·00	1·31	4·00
	Grain	19·45	26·86	29·12	0·99	3·02
	Stalk	53·28	68.53	77·69	2·29	7·01
1951	Cobs	24·10	37·60	44·00	1·37	4·19
	Grain	18·20	28·80	33·70	1·06	3·25
	Stalk	29·70	40·90	45·70	2·46	7·50
1952	Cobs	14·15	19·51	24·75	1·49	4·55
	Grain	11·60	16·00	20·08	1·22	3·73
	Stalk	33·50	44·90	52·20	1·53	4·68
1953	Cobs	14·44	28·57	38·84	1·28	3·90
	Grain	11·84	23·42	31·84	1·05	3·20
	Stalk	24·86	49·18	66·86	2·21	6·72

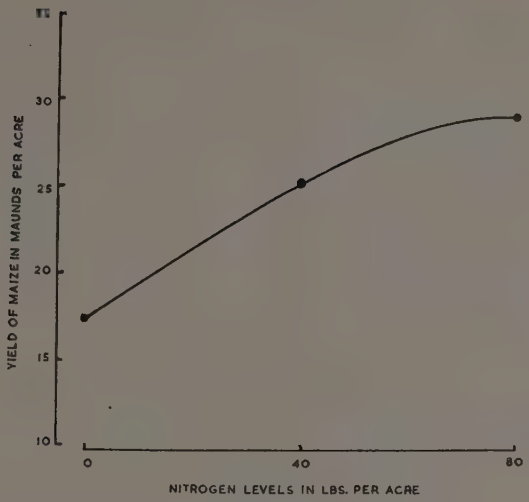

FIG. 1. RELATIONSHIP BETWEEN NITROGEN APPLICATION AND MAIZE GRAIN YIELD (1949-53)

TABLE III. YIELD OF MAIZE COBS, GRAIN AND STALK IN MAUNDS PER ACRE DUE TO PHOSPHATE

Year	Cobs, Grain and stalk	0 lb. P_2O_5	40 lb. P_2O_5	80 lb. P_2O_5	S.E. of mean ±	C.D. at 5%
1949	Cobs	37·34	39·28	40·22	0·71	2·16
	Grain	28·44	30·75	30·62	1·39	..
	Stalk	49·20	58·23	60·62	2·07	6·31
1950	Cobs	29·11	30·12	32·13	1·31	..
	Grain	23·78	25·16	26·48	0·99	..
	Stalk	61·25	68·09	70·16	2·29	7·01
1951	Cobs	31·30	38·70	35·80	1·37	4·19
	Grain	23·70	29·50	27·50	1·06	3·25
	Stalk	35·10	41·60	39·60	2·46	..
1952	Cobs	18·01	21·58	18.82	1·49	..
	Grain	14·62	17·69	15·37	1·22	..
	Stalk	43·67	43·85	43·16	1·53	..
1953	Cobs	25·32	27·91	28·63	1·28	..
	Grain	20·75	22·88	23·47	1·05	..
	Stalk	43·58	48·05	49·29	2·21	..

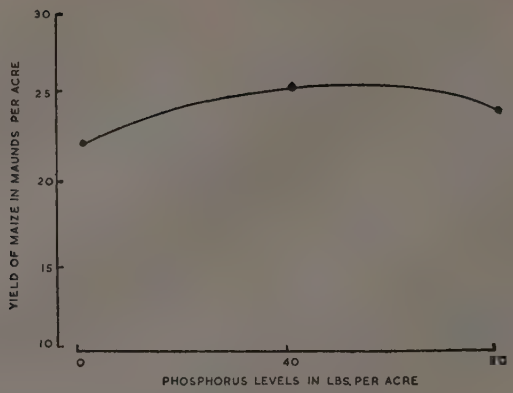

FIG. 2 RELATIONSHIP BETWEEN PHOSPHORUS APPLICATION AND MAIZE GRAIN YIELD (1949-53)

TABLE IV. YIELD OF MAIZE COBS, GRAIN AND STALK IN MAUNDS PER ACRE DUE TO POTASH

Year	Cobs gin and, stalk	ra0 lb. K_2O	60 lb. K_2O	S.E. of mean	C.D. at 5%
1949	Cobs	37·36	40·04	0·58	1·78
	Grain	29·52	30·36	1·14	..
	Stalk	54·22	27·82	1·69	..
1950	Cobs	30·92	29·99	0·97	..
	Grain	25·23	25·06	0·81	..
	Stalk	65·76	67·23	1·87	..
1951	Cobs	34·50	36·00	1·12	..
	Grain	27·40	28·40	0·87	..
	Stalk	37·40	39·90	2·01	..
1952	Cobs	18·47	20·47	1·22	..
	Grain	14·97	16·81	1·00	..
	Stalk	43·50	43·63	1·25	..
1953	Cobs	29·18	29·50	0·50	..
	Grain	23·92	24·18	0·41	..
	Stalk	50·23	5·78	0·86	..

The effect of nitrogen applications on the yield of maize has been well marked for the whole duration of the experiment. Increases in yield due to nitrogen doses were significant over the no nitrogen 'control'. In 1949 and 1950, differences

between yields due to 40 lb. and 80 lb. nitrogen per acre were not significant. In 1951, 1952 and 1953, however, 80 lb. nitrogen per acre produced significantly higher yields than those due to the dose of 40 lb. nitrogen. Nitrogen doses showed similar effect on the yield of cobs and stover (stalk). Phosphate applications at 40 lb. and 80 lb. P_2O_5 per acre increased the yields of grain, cobs and stover as compared to no phosphate treatment in all the years but the differences were significant only in 1951. Potassic fertilization of maize has not shown any response as reflected by the yields of grain, cobs and stover.

Wheat was grown in the intervening period. The question of residual cumulative effects of fertilizers applied each year has been examined later on.

A serial analysis of the five years' grain yield data indicated that effects due to nitrogen, phosphate, season, interaction between nitrogen and years are significant at 1 per cent level and those between nitrogen and potash and between phosphorus and nitrogen are significant at 5 per cent level (Appendix I). The results of the statistical analysis are summarised in Tables V, VI, VII and VIII.

TABLE V. YIELD OF MAIZE GRAIN IN MAUNDS PER ACRE
(Average for five years, 1949-53)

	Fertilizer	Yield (md.)	Percentage increase over control	Increase per lb. of nutrient over control (lb.)
Nitrogen	N_0—no nitrogen	17·45	..	
	N_1—40 lb. nitrogen	25·39	45·50	16·33
	N_2—80 lb. nitrogen	29·31	67·96	12·23
	S.E. of mean±	0·50		
	C.D. at 5%	1·52		
Phosphate	P_0—no phosphate	22·26		
	P_1—40 lb. P_2O_5	25·19	13·16	6·03
	P_2—80 lb. P_2O_5	24·65	10·74	2·46
	S.E. of mean±	0·50		
	C.D. at 5%	1·52		
Potash	K_0—no potash	23·92	..	
	K_1—60 lb. K_2O	24·18	1·09	0·36
	S.E. of mean±	0·41		

TABLE VI. YIELD IN MAUNDS PER ACRE FOR INTERACTION BETWEEN NITROGEN AND POTASH

	N_0	N_1	N_2
K_0	16·54	26·72	28·49
K_1	18·36	24·06	30·12
S.E. of mean	=±0·70		
C.E. at 5% level	= 2·15		

TABLE VII. YIELD IN MAUNDS PER ACRE FOR INTERACTION BETWEEN NITROGEN AND PHOSPHATE

	N_0	N_1	N_2
P_0	16·80	22·47	27·51
P_1	18·13	29·33	28·13
P_2	17·42	24·37	32·28
S.E. of mean	$= \pm 0{\cdot}86$		
C.D. at 5% level	$= 2{\cdot}63$		

TABLE VIII. YIELD IN MAUNDS PER ACRE FOR SEASON AND INTERACTION BETWEEN SEASON AND NITROGEN

Year	N_0	N_1	N_2	Mean
1949	26·17	31·85	31·78	29·94
1950	19·45	26·86	29·12	25·14
1951	18·22	28·80	33·70	26·93
1952	11·60	16·00	20·08	15·90
1953	11·84	23·42	31·84	22·36

S.E. of mean for years $= \pm 0{\cdot}72$
C.D. at 5% level $= 2{\cdot}02$
S.E. of mean for interaction years × nitrogen $= \pm 1{\cdot}24$
C.D. at 5% level $= 3{\cdot}50$

Increase in doses of nitrogen affected significant increases in yield. The combined data gave a difference of 7·94 maunds when the dose was increased from 0 to 40 lb. nitrogen, 11·86 maunds when the dose was increased from 0 to 80 lb., and 3.92 maunds when the dose was increased from 40 to 80 lb. nitrogen per acre. The average response between the levels of 0 and 40 lb. nitrogen was 16·33 lb. of maize grain, between 0 and 80 lb. nitrogen it was 12·23 lb. as against 8·06 lb. of grain between 40 and 80 lb. nitrogen calculated per lb. of nitrogen applied.

The difference in yield between 40 and 80 lb. P_2O_5 per acre was not significant and increases in both the cases were significant over the ' no phosphate ' control. On an average the response between the levels of 0 and 80 lb. P_2O_5 was 6·03 lb. and between 0 and 80 lb. P_2O_5 it was 2·46 lb. of maize grain per lb. of P_2O_5 applied per acre. When the dose was increased from 40 lb. to 80 lb. P_2O_5 per acre there was a reduction in yield to the extent of 1·11 lb. of maize grain per lb. of P_2O_5.

Application of potash did not effect significant increase in the yield of maize grain. The response was 0·36 lb. of grain per lb. of K_2O applied per acre when the dose was increased from 0 to 60 lb. K_2O.

Maize-grain yield during the year 1949 was significantly higher than those obtained during subsequent years. The yields for the years 1950 and 1951 did not

differ significantly and the increases in yield over 1952 and 1953 yield were significant in both the cases.

Since the plots were identical and manuring was done each year, it was considered necessary to critically analyse the data further to see if there was any cumulative effect of fertilizers. For this purpose b value (regression of yield on years) was worked out for each plot and data analysed for linear deterioration (Appendix II). The results indicated that rate of deterioration due to nitrogen levels only differed significantly. The results are given in Table IX.

TABLE IX. RATE OF DETERIORATION IN YIELD IN MAUNDS PER ACRE PER ANNUM

Treatment per acre	Deterioration (md.)
Nitrogen	
N_0—no nitrogen	3·65
N_1—40 lb.	2·77
N_2—80 lb.	0·89
S.E.M.	±0·36
C.D. at 5 %	1·10
Phosphorus	
P_0—no P_2O_5	2·44
P_1—40 lb.	2·31
P_2—80 lb.	2·53
S.E.M.	±0·36
Potash	
K_0—no K_2O	2·21
K_1—60 lb.	2·64
S.E.M.	±0·27

It may be seen that the rate of deterioration under 80 lb. nitrogen per acre dose was the minimum and significantly lower than 40 lb. nitrogen per acre and no nitrogen. There was no significant difference in the rate of deterioration between any two doses of phosphate and also between potash levels. It may, therefore, be stated that increasing doses of nitrogen only showed increasing response and maintained the yields at a fairly high level.

Nature of response: The variations due to nitrogen and phosphorus were split up into their respective linear and quadratic components and tested against the error variance for significance. The results are given in Table X.

TABLE X. TESTING THE NATURE OF RESPONSE (Grain)

Fertilizer source		S. S.	D. F.	M. S. S.	'F'
Nitrogen	L	7437·15	1	7437·15	283·25*
	Q	284·97	1	284·97	10·87*
Phosphorus	L	318·95	1	318·95	11·95*
	Q	207·78	1	207·78	7·91*
Error			13	26·25	

* Indicates significance at 1 per cent level and L and Q denote the linear and quadratic terms respectively.

Study of Table X reveals that the responses due to nitrogen and phosphate are non-linear. However, since the quadratic term is significant, second degree curves have been fitted to work out the optimum doses and responses. The response curves of nitrogen and phosphorus have been fitted in Figs. 1 and 2 and the equations are given below:

For nitrogen

$$Y=17{\cdot}45+0{\cdot}2486\times-0{\cdot}00126x^2$$

For phosphorus

$$Y=22{\cdot}26+0{\cdot}1166x-0{\cdot}00108x^2$$

OPTIMUM DOSES OF INDIVIDUAL FERTILIZERS

The yield equations for the average effect of five years (1949-53) have been given as $Y=a+bx+cx^2$ where Y is the yield of maize grain in maunds per acre for a dose of x lb. of fertilizer (nitrogen or phosphorus) per acre. The optimum dose has been calculated by the formula:

$$X_{op} = \frac{\frac{q}{p} - b}{2c}$$

where q and p are the cost of unit x and price of unit Y respectively. In the present case, the cost of one unit of nitrogen or phosphorus (q) is taken as Re. 0·8482 and Re. 0·7394 respectively. The optimum doses of nitrogen and phosphorus have been worked out individually for three price levels of one maund of maize (p) as Rs. 10, 12 and 14 respectively.

TABLE XI. OPTIMUM DOSES, RESPONSE AND NET PROFIT PER ACRE

	p Rs. per md.	Optimum dose (lb.)	Response (md.)	Net profit (Rs.)
Nitrogen	10	64·99	10·83	53·17
	12	70·60	11·27	75·36
	14	74·61	11·54	98·28
Phosphorus	10	19·80	1·89	4·26
	12	25·51	2·27	8·38
	14	29·60	2·51	13·26

It will be seen that the optimum dose of nitrogen lies between 65 and 75 lb. and that of phosphorus between 20 and 30 lb. per acre for prices of maize grain varying from Rs. 10 to 14 per maund.

OPTIMUM DOSES OF FERTILIZER COMBINATIONS

Since the interaction between nitrogen and phosphorus was significant, a response surface function was fitted to the data from N P table. The fitted response function is $Y=16{\cdot}698+0{\cdot}22285N-0{\cdot}001257N^2+0{\cdot}09052P-0{\cdot}00107P^2+0{\cdot}00065NP$.

The optimum dose of fertilizers is that combination which maximises the profit. It is obtained when the marginal added income is just equal to the marginal added cost of each fertilizer. Taking the quadratic response surface in the form,

$Y = a + bx + cx^2 + dz + ez^2 + fzx$, then the optimum dose (NP) is given by

$$N = \frac{f(d - \frac{r}{p}) - 2e(b - \frac{q}{r})}{4ce - f^2}$$

$$P = \frac{f(b - \frac{q}{p}) - 2c(d - \frac{r}{p})}{4ce - f^2}$$

where p, q and r are the costs of one unit each of maize grain, nitrogen and phosphorus respectively. The optimum doses of fertilizer combinations worked out for three price levels of one maund of maize (p) as Rs. 10, 12 and 14 respectively are presented in Table XII along with the response and net profit per acre.

TABLE XII. OPTIMUM DOSE OF FERTILIZERS, RESPONSE AND NET PROFIT PER ACRE

p Rs. per md.	Optimum doses N	P_2O_5 (lb.)	Response (md.) (lb.)	Net profit per acre (Rs.)
10	61·68	26·68	11·65	44·75
12	69·25	34·32	12·79	69·25
14	74·88	40·07	13·48	95·58

It may be concluded from the data presented above that the optimum doses of fertilizer combinations vary from 60 to 75 lb. of nitrogen and 25 to 40 lb. of P_2O_5 per acre for price levels at Rs. 10 to 14 per maund of maize grain. The optimum levels of fertilizers, therefore, lie within the ranges experimented upon.

SUMMARY

A fertilizer field trial on maize was carried out on a sandy loam soil at the Indian Agricultural Research Institute, New Delhi over a period of five years (1949-53). The object of the investigation was to study the effect of varying doses of fertilizer nitrogen (0, 40 and 80 lb. per acre), phosphorus (0, 40 and 80 lb. per acre) and potash (0 and 60 lb. per acre) and their combinations on the yield of maize with a view to working out an optimum dose of fertilizers. The results are summarized below:

Increasing doses of nitrogen gave increased yields and the difference in yield between any two levels was significant. On an average extra yields obtained due to 40 and 80 lb. nitrogen were 7·94 and 11·86 maunds per acre thus giving a response of 16·33 and 12·23 lb. of maize grain per lb. of nitrogen respectively.

Phosphate applications also enhanced the yields significantly but the magnitude of response was much poor as compared to that due to nitrogen. Extra responses

due to 40 and 80 lb. P_2O_5 doses over the control were 2·93 and 2·39 maunds of grain, the response being 6·03 and 2·46 lb. per lb. of the nutrient respectively.

Potassic fertilizer applied to maize did not influence the yield greatly or significantly.

The rate of deterioration in yield under the 80 lb. nitrogen per acre dose was significantly lower than that under 40 lb. or the control. Phosphorus and the potassic doses did not show differential effects.

Averaged over the five years, the response of maize to nitrogen and phosphorus were quadratic. The yield equations are given below:

For N $Y = 17{\cdot}45 + 0{\cdot}2486N - 0{\cdot}00126N^2$

For P $Y = 22{\cdot}26 + 0{\cdot}1166P - 0{\cdot}00108P^2$

For N and P combination

$Y = 16{\cdot}698 + 0{\cdot}22285N - 0{\cdot}001257N^2 + 0{\cdot}09052P - 0.00107P^2 + 0.00065NP$

The optimum economic dose of fertilizer combinations varied from 60 to 75 lb. of nitrogen and from 25 to 40 lb. of P_2O_5 per acre for price levels of Rs. 10 to 14 per maund of maize grain.

ACKNOWLEDGEMENTS

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APPENDIX I

ANALYSIS OF VARIANCE TO TEST SIGNIFICANCE OF TREATMENT DIFFERENCES

Source	S.S.	D.F.	M.S.S.	Variance ratio
Blocks	1,261·8878	5	252·3776	9·612†
N	7,722·2212	2	3,861·0606	147·055†
P	522·4035	2	261·2018	9·948†
K	5·3389	1	5·3389	0·203
N×K	339·4121	2	169·7061	6·463*
P×K	141·3568	2	70·6784	2·730
(N×P)J	153·7878	4	108·2250	4·122*
(N×P)IC	279·1123			
(N×P×K)J	92·1764	4	52·0724	1·983
(N×P×K)IC	116·1134			
Error (a)	341·3250	13	26·2558	
Years	7,196·0119	4	1,799·0030	54·996†
Years×N	1,511·0227	8	188·8778	5·774†
Years×P	184·9321	8	23·1165	0·707
Years×K	159·1050	4	39·7763	1·216
Years×N×P	722·1413	16	45·1338	1·379
Years×N×K	185·1240	8	23·1405	0·715
Years×P×K	176·8978	8	22·1122	0·676
Years×N×P×K	491·8933	16	30·7433	0·939
Error (b)	2,355·2159	72	32·7113	
Total	23,957.3792	179		

† and * indicate significance at 1 and 5 per cent respectively.

APPENDIX II

ANALYSIS OF LINEAR DETERIORATION (B) TO TEST THE SIGNIFICANCE OF THE CUMULATIVE EFFECT OF FERTILIZERS

Source	S.S.	D.F.	M.S.S.	Variance ratio
Blocks	2,853·16	5	570·63	2·5
N	8,462·33	2	4,231·16	15·408*
P	50·42	2	25·21	1
K	285·61	1	285·61	2
N×K	1,068·44	2	534·22	2
P×K	350·48	2	175·24	1
(N×P)J	118·13	4	139·60	1
(N×P)IC	440·28			
(N×P×K)J	106·62	4	185·05	1
(N×P×K)IC	525·60			
Error	3,569·92	13	274·61	
Total	17,830·99	35		

*Indicates significance at 1 per cent level.

EFFECT OF VARIATION IN THE DEPTH OF CULTIVATION, WITH AND WITHOUT MANURE, ON THE YIELD OF MAIZE

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In the second article of the series the results of seed-bed preparation for maize with alternative forms of tillage implements, on a sandy loam soil, were discussed. Though improvement in yield as a result of deep ploughing was observed, the differences were not found to be significant. The effect of soil inversion was also not marked on this soil-type.

Maize has a wide range of adaptability in regard to soil and climate. It responds well to cultivation and manuring. The problem of raising its production should, therefore, be looked into by keeping these factors in view.

With this background the project was switched over to a heavy land in the year 1950-51 for further study. This paper purports to present results achieved during the period of five years.

EXPERIMENTAL PROCEDURE

The experiment was laid out in a split-plot design on an irrigated piece of land on the I.A.R.I. Farm. Details are furnished below:

Treatments

(a) *Main plot:* C_1—Ploughing nine to ten inches deep with tractor (soil inversion) plough in the first instance, followed by normal cultivation with tractor implements to achieve a suitable seed-bed.

C_2—Ploughing upto a depth of five inches, with soil inverting plough drawn by bullocks, followed by normal cultivation with the local indigenous plough.

C_3—Ploughing with local indigenous plough upto a depth of four to five inches without inversion, throughout the season.

C_4—Tractor discing to a depth of about four inches.

(b) *Sub-plot:* N_0—no manure

N_1—farmyard manure—40 lb. nitrogen per acre

N_2—farmyard manure—80 lb. nitrogen per acre

N_3—farmyard manure—120 lb. nitrogen per acre

Layout: split-plot design with 4×4 treatment combinations and three replications in the first year, followed by four replications in each subsequent year.

Rotation: Maize-berseem-fallow-wheat. A leguminous crop (berseem) and a fallow were included in the rotation to keep the land in good tilth. Soil used for the purpose was a clayey loam having the following physical composition and chemical constitution.

Soil seprates	*Percentage*
Coarse sand	2·7
Fine sand	33·5
Silt	32·6
Clay	26·4
Chemical constitution	
Total soluble salts	0·92
Total P_2O_5	0·14
Total K_2O	0·45
Available P_2O_5	0·02
Available K_2O_5	0·05
Organic N	0·05

The land under experiment was fairly well-drained, uniform in texture, and of average fertility. The cultivations given to maize were about three to four with tractor and six with bullock-drawn implements.

RESULTS

In order to have an idea of the work for the period as a whole the data relating to different years were pooled and analysed serially. As there were only three replications in the first year, which were increased to four in subsequent years, the results of 1951 could not be linked with the subsequent years and have been analysed separately. The data obtained are summarised in the following Table:

TABLE I. YIELD OF GRAIN OBTAINED UNDER DIFFERENT CULTIVATION TREATMENTS FOR INDIVIDUAL YEARS AS WELL AS THE AVERAGE FOR 1952-55

Treatments	Years					Overall av. for depth of cultivation (1952-55)
	1951	1952	1953	1954	1955	
C_1	11·23	14·00	10·45	14·22	12·48	12·71
C_2	9·03	12·82	8·96	13·79	11·21	11·70
C_3	9·12	12·91	12·67	12·20	10·10	11·97
C_4	6·94	8·96	9·17	13·27	11·87	10·82
Overall av. for years	9·08	12·19	10·31	13·37	11·34	
S.Em.	0·89	± 1·13	± 0·68	± 0·60	± 0·59	± 0·47
C.D. 5%		3·63	2·14	..	..	..
S.Em. (for years 1952-55)			± 0·44			
C.D. 5%			1·62			

The above analysis was done after testing the homogeneity of error variance by 'M' test which was not found to be significant. The differences between years were found to be significant; the cultural treatments, however, were not so.

It is evident from the above Table that maize crop did not respond to the variations in the depth of cultivation though the seed-bed prepared by disc harrow was not conducive to high yield. A slightly increased yield was obtained with the deep ploughing.

TABLE II. THE EFFECT OF VARYING DOSES OF MANURE ON THE YIELD OF MAIZE GRAIN

Treatments	Years					Overall av. for manuring (1952-55)
	1951	1952	1953	1954	1955	
N_0	8·42	8·57	8·30	12·04	9·52	9·61
N_1	8·47	12·06	9·92	13·81	10·76	11·64
N_2	9·72	12·36	10·72	13·43	12·62	12·28
N_3	9·70	15·70	12·26	14·18	12·46	13·62
S.Em.	± 0·83	± 1·04	± 0·35	± 0·77	± 0·66	± 0·51
F. test	Not sig.	Sig.	Sig.	Not sig.	Sig.	Sig.
C.D. 5%	..	2·99	1·00	..	1·91	1·46

Table II indicates marked effect of manure on the yield. With the increase in the dose of manure the yield also increased though not proportionately. But the effect of highest dose of manure on the yield is very significant. An extra yield of 4 md. of grain was obtained over the check. The difference between N_2 and N_3, however, is not significant.

Contrary to cultural treatments the differences in manures have been found to be significant. The interaction between manurial treatments and years was not significant.

TABLE III. RESPONSE OF MAIZE TO DIFFERENT LEVELS OF FERTILITY
(Analysis of variance)

Source	DF	1952		1953		1954		1955		Serial analysis	
		Mean sum of square	Variance ratio	Mean sum of square	Variance ratio	Mean sum of square	Variance ratio	Mean sum of square	Variance ratio	Mean sum of square	Variance ratio
Block	3	492·47	..	126·68	..	316·52	..	67·22	..	114·01	..
Cultivation	3	330·26	3·36	186·36	6·24*	39·83	2·12	44·01	2·46	127·22	2·82
Error (a)	9	98·32	..	29·85	..	18·77	..	17·83	..	45·15	..
Nitrogen	3	576·42	7·86*	175·69	22·64†	45·19	1·52	112·56	4·92†	586·00	11·01
Linear	1	1,597·57	21·78†	520·20	78·7	94·06	3·17 Not Sig.	294·50	12·91†	1,689·69	31·77
Residual	2	65·85	0·89	3·43	0·44	20·77	0·69	21·50	0·94	33·58	0·68
Interaction	9	30·28		8·59		29·70		17·20		27·16	
Error (b)	36	73·33		7·76				22·87		53·19	

The response to different levels of fertility was worked out for individual years as well as period of four years. The analysis is shown in the above Table with a linear type of response.

TABLE IV. INTERACTION BETWEEN CULTIVATION AND MANURIAL TREATMENTS (YIELD IN MAUNDS PER ACRE OF MAIZE GRAIN)

Treatments	C_1	C_2	C_3	C_4
N_0	9·66	10·66	9·93	8·19
N_1	12·78	10·61	11·70	11·47
N_2	13·07	12·24	12·68	11·20
N_3	15·35	13·28	13·58	12·42
		F. Test Not significant		
		S.Em. ± 1·01		

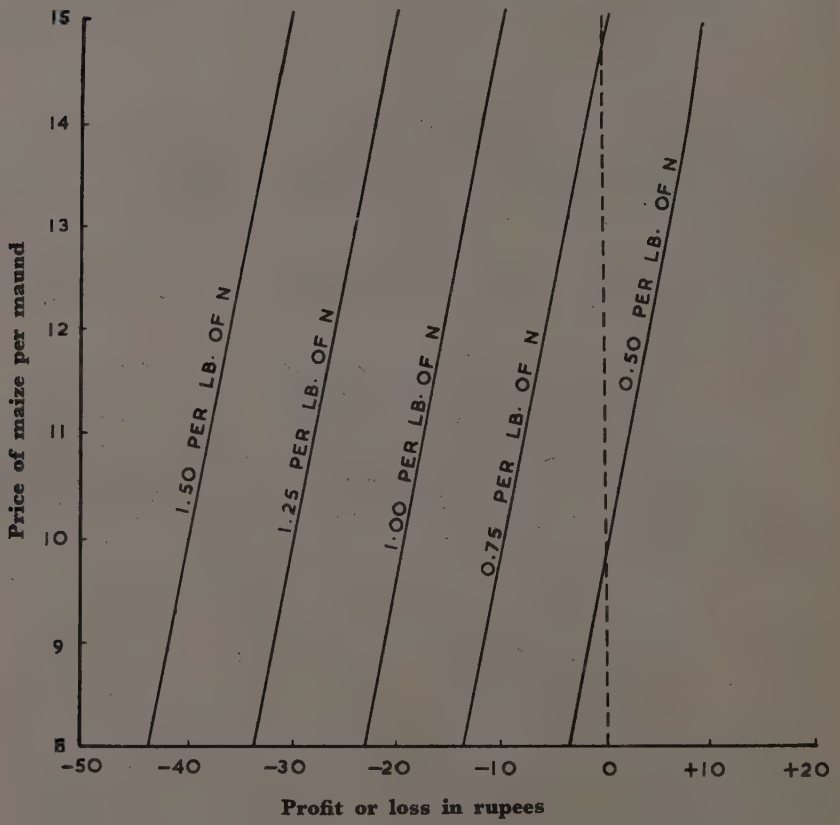

FIG. 1. INTER-RELATIONSHIP OF EXTRA DOSE OF 80 LB. N TO PRICE PER MAUND OF MAIZE

Though the interaction in Table IV was not found to be significant, yet the trend is interesting. With the increase in the dose of manure the yield under all the cultivation treatments also increased. The highest return was obtained in the case of C_1 N_3 combination indicating the necessity of manuring for deep ploughing in order to raise the production potential of land.

Economics of the rate of manuring in relation to price levels

Since the response was linear, the economics of manurial treatments was worked out. It has been indicated (Fig. 1) that at a cost of 50 nP. per lb. of nitrogen and a price range of Rs. 10/- to Rs. 15/- per maund of maize grain the manuring with N_1 treatment is economical.

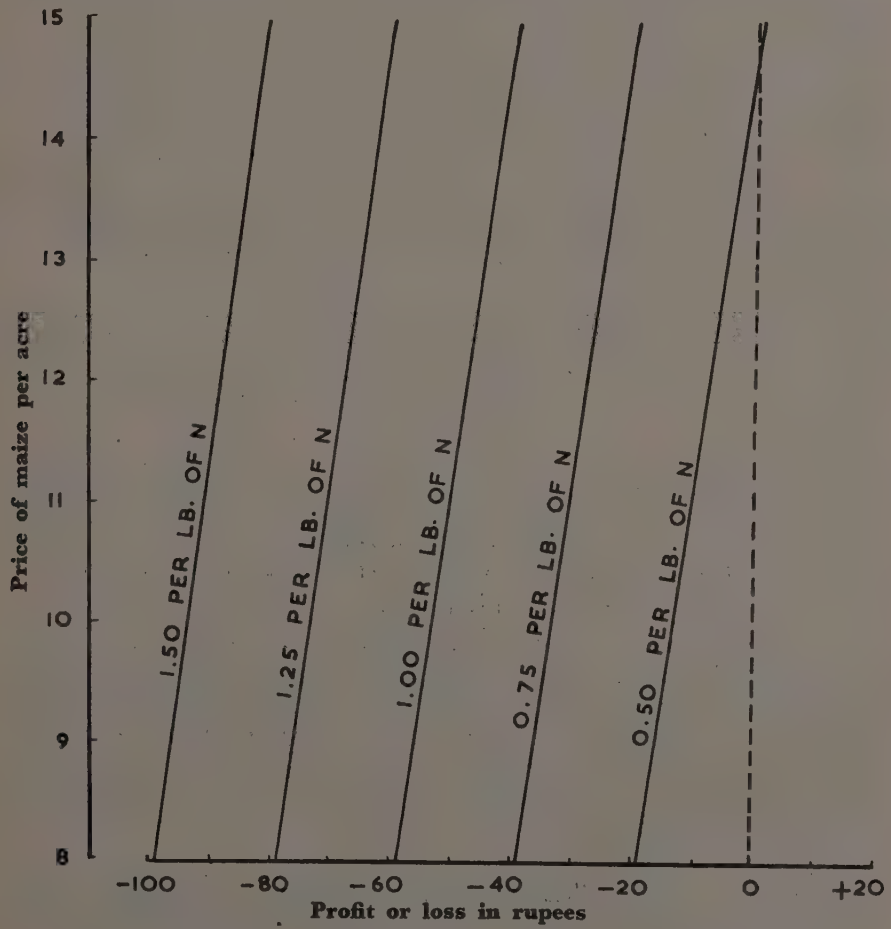

FIG. 2. INTER-RELATIONSHIP OF EXTRA DOSE OF 80 LB. N/ACRE TO PRICE PER MAUND OF MAIZE

With the increase in the price of nitrogen to 75 nP. per pound it touched profitable limit only when the price of grain was also raised to Rs. 15/- per maund. If the cost of manure is increased further, manuring becomes uneconomical.

In Fig. 2, a slight profit has been shown with a N_2 treatment when the price of grain remains Rs. 15/- per maund and that of nitrogen at 50 nP. per lb.

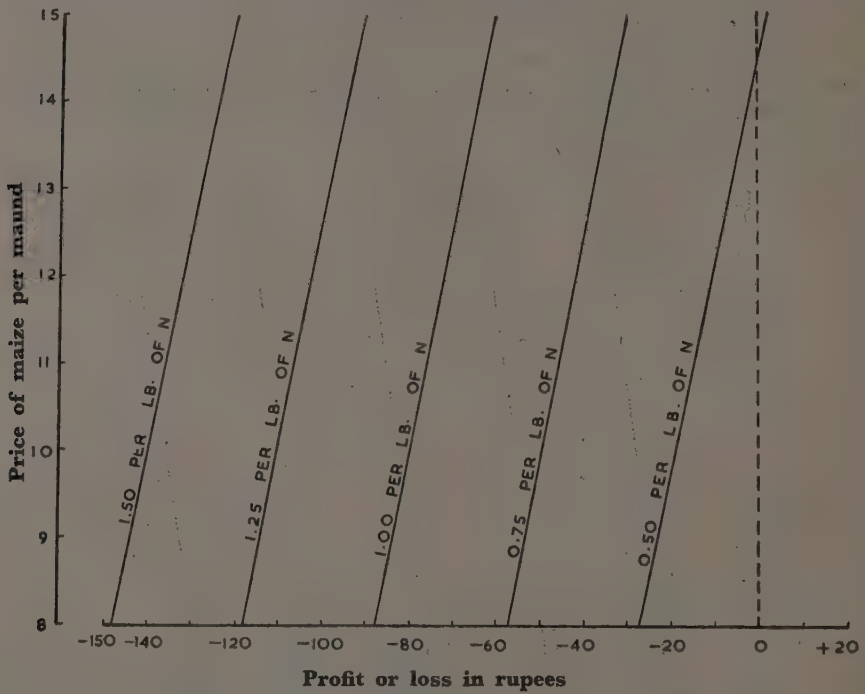

FIG. 3. INTER-RELATIONSHIP OF EXTRA DOSE OF 120 LB. N TO PRICE PER MAUND OF MAIZE

DISCUSSION

The results obtained in this study confirm those of the previous experiment conducted on the light soils. It is increasingly evident that deep ploughing under the soil conditions as prevalent at Delhi is not necessary. It was also not found beneficial on most soils by many workers. To quote a few, the names of Morrow and Gardner [1892], Grandeau [1894], Noll [1913], Sewell [1919], Torstensson [1943], Worzella [1951] and Khan and Mathur [1954] may be mentioned. Alderfer [1952], giving reason why deep ploughing doesn't pay on most soils, is of the opinion that poor physical condition is not the problem there.

Unlike the previous study, the effect of manures was marked in this case. The effect of farmyard manure in boosting the yield is well-known. It has been noted by Russell [1938], Chaudhry [1943], Panse *et al.* [1947], Stewart [1947], Sethi and Chatterji

[1948], and Carpenter [1948] besides many others who have observed the beneficial effect of farmyard manure for a healthy plant growth.

Although the interaction between cultivation and manuring has not been found to be significant, yet the data reveal interesting facts. A difference of 5·69 maunds of grain per acre was obtained over no manure with C_1N_3. Similar increase with deep ploughing was obtained by Russell [1956] when high level of fertilizers was used. The lowest yields were again obtained with the discing, irrespective of the added manure. This confirms the earlier finding that because of great pulverization of soil the land gets packed and results in low yield.

SUMMARY AND CONCLUSION

Ploughing deeper than five inches is not conducive to increase yields significantly.

On lands where weed is not the problem the effect of soil inversion is not marked.

To pulverize seed-bed into a dust-mulch through disc is not a desirable practice.

It is evident from this study that country plough is a good stabilizer of yield.

When production base is increased by deep ploughing the effect of high level of manuring becomes pronounced.

ACKNOWLEDGEMENTS

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RESPONSE OF CERTAIN VARIETIES OF SUGARCANE TO DIFFERENT FERTILITY LEVELS

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The first thing that comes to the mind of a progressive farmer is the selection of a crop variety which would ensure best return from his land. With the advance in science and technological progress, it is now possible to offer a large number of varieties to choose from. In the case of sugarcane especially, as with any other crops, the improvement in variety has played a very important part for raising production. During the early years of introduction the role of improved varieties of sugarcane was so spectacular as to step up production by about 50 per cent over the local or 'desi' canes merely due to the genetic potential of the new seed.

Much benefit, no doubt, has been secured by introducing seed of higher yielding type in the village repertoire, but full response from a better type of seed has always been contingent upon the provision of suitable environment. Varieties with higher yield tendency demand a higher standard of farming in order to give full expression to their inherent qualities. By stressing this we do not mean to say that no advantage would accrue by the introduction of improved varieties of crops under ordinary farming conditions, but what we maintain is, to get best out of an improved variety the farming standard should also be of high order.

In the light of the above remarks an investigation entitled 'Response of certain varieties of sugarcane to different fertility levels' was started in the year 1953 on the farm of the Indian Agricultural Research Institute, New Delhi.

The results of four years are presented in this paper.

EXPERIMENTAL METHOD

The experiment was laid out in a split-plot design on irrigated soils ranging from loam to heavy loam. The treatments consisted of the following:

Varieties	*Nitrogen doses*
V_1 — B.O. 11	N_0—No nitrogen (control)
V_2 — C.O. 312	N_1—40 lb. nitrogen per acre
V_3 — Co. 647	N_2—80 lb. nitrogen per acre
V_4 — Co. 659	N_3—120 lb. nitrogen per acre
V_5 — Co. 739	
V_6 — Co. 797	

Basal dressing of F.Y.M. at ten tons per acre was applied uniformly to all plots in the first three years, and the whole field was green manured in the second and the fourth years. No F.Y.M. was applied in the fourth year. The fertilizers were applied after the tillering was completed in each case.

The climate of Delhi is typically sub-tropical. The average rainfall is about 25 inches. The mean relative humidity ranges from 30 to 91 per cent.

RESULTS

In order to have a general picture of the work, the data relating to individual years and the average for a period of years have been analysed statistically and shown in the Tables below.

TABLE I. AVERAGE YIELD OF STRIPPED CANE (maunds per acre)

Varieties	Years				Average
	1953–54	1954–55	1955–56	1956–57	
B.O. 11	564·45	792·13	732·93	690·82	695·08
Co. 312	494·53	717·48	612·46	643·61	617·02
Co. 647	549·05	919·04	793·84	849·74	777·92
Co. 659	476·83	774·05	724·68	746·08	680·41
Co. 739	463·43	670·72	678·34	680·03	623·14
Co. 797	522·69	834·42	698·89	781·75	707·94
'F' test	Not sig.	Sig.	Not sig.	Sig.	Sig.
S.Em. ±	24·68	46·90	54·04	25·54	14·70
C.D. 5%	..	147·78	..	80·25	46·30

The average yield of millable cane was significantly better in case of Co. 647 than all other varieties in the test. This was followed by Co. 797, which, for the purpose of statistical significance, may be bracketed with Co. 659 and B.O. 11. The lowest yield was obtained from Co. 312, the standard variety. The difference between Co. 312 and Co. 739 was not statistically significant.

TABLE II. EFFECT OF NITROGEN ON THE YIELD OF SUGARCANE (maunds per acre)

Fertilizer dose lb./acre	Years				Average
	1953–54	1954–55	1955–56	1956–57	
0	506·46	747·48	665·32	668·41	646·91
40	546·46	790·49	692·51	711·71	685·29
80	527·36	812·15	719·34	742·05	700·23
120	467·50	788·44	746·16	805·86	701·99
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
S.Em. ±	11·40	13·73	11·04	10·16	5·43
C.D. (5%)	32·83	39·20	31·80	29·08	15·60

With the increase in the dose of nitrogen the yield also increased, though the differences were narrowed down subsequently amounting to almost nil in the case of highest dose. It may be evident from Table II that the highest increase was registered with the first dose and this was significant. In the case of second dose the difference may also be considered as significant if half a maund, by which it was short, is ignored. The highest dose does not seem to have produced any effect.

The interaction between varieties and nitrogen was not found to be significant. It would, however, be interesting to see the trend of differential response of varieties to fertilizer doses.

TABLE III. RESPONSE OF VARIETIES TO LEVELS OF NITROGEN

(Pooled; yield of cane in maunds per acre)

Varieties	Nitrogen in lb. per acre			
	0	40	80	120
B.O. 11	656·55	684·25	712·66	725·83
Co. 312	586·17	631·54	623·03	626·22
Co. 647	736·63	793·24	786·44	794·18
Co. 659	639·19	676·64	706·39	698·38
Co. 739	605·97	612·04	639·20	634·41
Co. 797	652·81	694·74	751·86	731·28
'F' test	Not significant			
S.Em.	± 13·31			

Table III shows that different varieties have reacted differently with variable levels of nitrogen. In the case of Co. 312 and Co. 647 the optimum dose seems to be 0 lb. N per acre in conjunction with basal dressing. For the rest of varieties, except B.O. 11, the highest yield was obtained with 40 lb. N per acre.

In order to have an idea of the sugar output the following Table has been prepared.

TABLE IV. QUALITY OF JUICE AND SUGAR OUTPUT PER ACRE

Variety	Sucrose (per cent)	Total CCS.
B.O.	18·26	90·57
Co. 312	18·61	82·74
Co. 647	16·90	93·66
Co. 659	18·96	89·68
Co. 739	18·73	83·63
Co. 797	18·34	92·39

Two new varieties Co. 647 and Co. 797 have come out to be the best in regard to per acre yield of cane as well as sugar. Due to high sucrose content Co. 797 has considerably made up the loss in tonnage when compared with Co. 647.

DISCUSSION

In the course of this investigation, it was revealed that Co. 647 produced the largest number of tillers as compared with other varieties. This may perhaps be the reason that it was able to surpass all other varieties in yield. This finding has been confirmed by many workers including Barber [1918], Quintus [1923], and Raheja and Sekhon [1954]. They observed generally that with the increase in the number of canes per clump the weight also improved.

The other varieties for example, Co. 797 and B.O. 11, which respectively hold next positions in regard to yield were found to have lesser number of tillers than Co. 647.

With regard to effect of nitrogen on the yield of cane (Table II), it is observed that its effect was marked. Similar effect was also noticed by numerous workers. To mention a few, Turner [1933], Das [1936], Borden [1948] and Garrucho [1957] would be sufficient. A per acre dose of 80 to 100 lb. nitrogen to cane was considered suitable by Khan *et al.* [1954], Rao and Narasimham [1954] and others.

Though the interaction between varieties and nitrogen levels was not found to be significant, interesting trends have been noted. It appears that varieties differ in their response towards nitrogen. This finding is confirmed besides others by Beauchamp [1942] and Van Ginnekan [1942]. The most efficient use of nitrogen was made by Co. 647 with as little extra dose of nitrogen as 40 lb.

Because of poor juice quality variety Co. 647, which produced the highest tonnage, could not increase the output of sugar in the same ratio.

SUMMARY AND CONCLUSION

It may be concluded from this study that the two new varieties Co. 647 and Co. 797 are the most outstanding. They have out-yielded the old and established variety Co. 312, not only in the tonnage of cane but also in the sugar output.

In regard to nitrogen, almost highest response was obtained with as small an additional dose as 40 lb. by Co. 647. This was also helpful in lowering the cost of production. Co. 797 proved to be a good variety both from the point of view of yield and sugar output.

ACKNOWLEDGEMENTS

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STUDIES ON TILLAGE

VII. EFFECT OF VARIATION IN DEPTH OF CULTIVATION, WITH AND WITHOUT MANURE, ON THE YIELD OF WHEAT

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In the fifth article of this series, the results of seed-bed preparation for maize with alternative forms of tillage implements were discussed. This paper presents data of the same project with yet another crop in rotation, i.e., wheat. Though improvement in yield as a result of deep ploughing was indicated on maize, the differences were not found to be significant. The effect of soil inversion was also not marked in heavy soils.

Wheat is a tilled crop which responds well to cultivation, and is grown under a wide range of soil types. It seems, therefore, desirable to study the preparation of seed-bed as effected by different implements of tillage under varying conditions of soil. The tillage is not only the major item in the cultivation for wheat but also the costliest one. Any attempt to rationalize the system of soil management in cereal farming will go a long way to help solve a problem which is still considered to be complex, controvertial and speculative.

Keeping this in view, a project was started on heavy soils in the year 1950-51. The results achieved during a period of five years are described in the following pages.

EXPERIMENTAL PROCEDURE

An area of about four acres of land consisting of 2·7 per cent coarse sand, 33·5 per cent fine sand, 32·6 per cent silt and 26·4 per cent clay was taken up in Main Blocks 12 B and 15 A of the farm attached to the Division of Agronomy and utilized for experimental purpose. The details of treatments were as follows:

Main Plot

C_1—Ploughing nine to ten inches deep with tractor soil inversion plough in the first instance, followed by normal cultivation with tractor implements to achieve a suitable seed-bed

C_2—Ploughing up to a depth of five inches, with soil inverting plough drawn by bullocks, and followed by normal cultivation with the local ' Country ' plough.

C_3—Ploughing with local ' Country ' plough up to a depth of four to five inches without inversion, throughout the season

C_4—Tractor discing to a depth of about four inches.

Sub-plot

N_0—No manure

N_1—Farmyard manure 40 lb. nitrogen per acre

N_2—Farmyard manure 80 lb. nitrogen per acre

N_3—Farmyard manure 120 lb. nitrogen per acre

Lay out: Split-plot design with 4×4 treatment combinations and three replications in the first year, followed by four replications each subsequent year.

Rotation: Maize-berseem-fallow-wheat. A leguminous crop (berseem) and a fallow were included in the rotation in order to keep the land in good tune.

The land under experiment was fairly well-drained, uniform in texture, and of average fertility.

RESULTS

In order to have an idea of the work for the period as a whole, the data relating to different years were combined and analysed. As there were only three replications in the first year, which were increased to four in subsequent years, the results of 1950-51 could not be linked with the subsequent years and have, therefore, been analysed separately. The results obtained are summarized in the following Tables.

TABLE I. YIELD OF INDIVIDUAL YEARS AS WELL AS AVERAGE YIELD OF GRAIN FOR 1951-55

(maunds per acre)

Treatments	Years					Overall av. for depth of cultivation (1951–55)
	1950–51	1951–52	1952–53	1953–54	1955–56	
C_1	24·39	25·63	25·21	15·78	32·83	24·86
C_2	22·66	26·52	28·48	15·50	33·21	25·93
C_3	24·05	26·31	30·01	17·97	32·28	26·64
C_4	22·07	22·53	25·66	16·90	28·80	23·47
Yearly average	..	25·16	27·34	16·69	31·79	..
'F' test	Not sig.	Sig.	Not sig.	Sig.	Sig.	Sig.
S.Em.	± 1·22	± 0·51	± 1·77	± 0·48	± 0·89	± 0·68
C.D. 5%	..	1·63	..	1·41	2·80	2·19
S.Em. for years (1951–55)	=± 0·55					
C.D. 5%	= 1·52					

The differences between years were found to be significant but the cultivation treatments were not so. Contrary to highest yield obtained with the deep ploughing in maize, the highest record shown in this study was with the local country plough. The lowest yield was, however, obtained with disc harrow in this case as well. The wheat crop doesn't show response to deep tillage.

It is evident from the above Table that manure helped to push forward the yield generally, but the rate of increase was not uniform. The highest yield was obtained with the highest dose (120 lb.) of nitrogen, making a difference of 3·37 md. grain per

acre in its favour. The differences were not statistically significant between N_0 and N_1 or N_1 and N_2 though N_2 is significantly better than the blank. In the case of N_3, however, significant increase over all other treatments has been obtained.

The response to different levels of fertility was worked out and found to be of linear type.

TABLE II. EFFECT OF MANURE ON THE YIELD OF WHEAT GRAIN

(maunds per acre)

Treatments	Years					Overall av. (1951–55)
	1950–51	1951–52	1952–53	1953–54	1954–55	
N_0	21·60	23·47	24·30	15·78	31·16	23·68
N_1	22·77	24·69	26·11	15·72	32·21	24·68
N_2	23·78	26·35	27·93	17·15	30·64	25·52
N_3	24·98	26·47	31·02	17·59	33·11	27·05
'F' test	Not sig.	Sig.	Sig.	Sig.	Not sig.	Sig.
S.Em.	± 1·33	0·68	0·89	0·47	1·06	0·48
C.D. 5%		1·95	2·56	1·40		1·20

TABLE III. INTERACTION BETWEEN CULTIVATION AND MANURE

(yield of wheat grain in maunds per acre)

Treatments	C_1	C_2	C_3	C_4
N_0	24·26	24·06	23·72	23·04
N_1	24·62	24·43	27·24	22·72
N_2	25·54	26·72	26·87	22·50
N_3	25·14	28·23	29·16	25·65

S.Em ± 0·83
'F' test Not significant

The interaction has not been found to be significant and it has been tabulated simply to study the trend. The highest response was noted with C_3N_3 and C_2N_3 treatments, which correspond with the yields obtained under cultivation treatments. The stabilizing effect of manure on yield was more pronounced in case of those cultivation treatments which were leading.

Economics of manuring: The economics of rate of manuring was worked out and it was found that doses at the rate of 40 and 80 lb. nitrogen per acre were not profitable. A small profit accrued at 120 lb. level of nitrogen provided the price of wheat grain ranged from Rs. 18/- to Rs. 20/- per maund and the cost per pound of nitrogen did not increase beyond Re. 0·50.

DISCUSSION

The findings of this investigation confirm those of the previous one carried out with similar treatments on the light soil. The fact, that deep ploughing is not needed on well-drained soils for wheat, has been clearly brought out in this study. Additional confirmatory evidence in this regard may be obtained from various workers the world over. Russell and Keen [1941] at Rothamsted did not observe appreciable difference in a wheat, marigolds, barley rotation between four and eight inches of ploughing. Experimental results with deep tillage in Europe as reported by Woolney [1895], Roemer [1927], Iversen [1934], Morgenroth [1942], Torstennson and Enge [1943] gave the general trend that crop yields were little increased by deep ploughing. The experience of American investigators both in corn and wheat belt is that yields are insensitive to variation in the depth of tillage. Russell [1956] described results of about eight years' experiments on commercial farms in U.K. He found no appreciable difference in wheat yield due to deep tillage.

The Indian workers Allan [1935], Johnston [1938], Khan [1953], and Khan and Mathur [1954] besides others also did not find wheat responding to deep cultivation.

Discing has again proved to be ineffective due to great pulverization of the soil resulting in a fluffy seed-bed.

Contrary to the previous study, the effect of ' manure ' is marked in this case. The highest yield was obtained with the heaviest dose of 120 lb. nitrogen per acre. The increase in grain and straw yield due to high doses of nitrogen has been reported by Chapman [1927], Hartley and Greenwood [1929], Black *et al.* [1946] and others.

The interaction between cultivation and manuring has, though not been found significant, yet the trend is interesting. Highest yield was obtained with $C_3 N_3$ treatment followed by C_2N_3. The increase over the check was of 5·44 and 4·17 maunds grain respectively. The tendency remained the same as with main plot treatments.

SUMMARY AND CONCLUSION

It may be said that wheat crop does not respond to cultivation deeper than five inches even on heavy soil which should, as far as possible, be avoided. It was also observed that on lands where weed-infestation is not the problem the effect of inversion is not marked. Discing creates a fluffy seed-bed which results in lowering the yield. Country plough appears to be a suitable implement for preparing seedbed for wheat.

Inspite of a rotation which included a legume and a fallow to precede wheat crop, the effect of added doses of nitrogen in the form of farmyard manure was marked. The trend was found to be linear. Though the increase in yield at 120 lb. level of nitrogen was substantial yet the return in terms of money was nominal.

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A STUDY OF SOME ASPECTS OF THE PROBLEM OF WHEAT PRODUCTION AND VARIETAL IMPROVEMENT IN THE NORTH INDIAN HILLS

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There will always exist the desirability of increasing the food production in a country with a growing population. The necessity for our making an all-inclusive effort for stepping up the per acre yields of our premier food grains at the present time can hardly be over-emphasized now as the country cannot afford to import any food from abroad. The present study is directed to bring out the importance of a few of the ecological factors that affect the physiology and morphology of the wheat plant in the ways that are related to yield per unit area. The data presented show that some of the ecological factors can be so manipulated as would result in appreciable yield increases, besides their pointing to the evidence with regard to the desirability of our altering the existing breeding and varietal testing methodology for an accurate evaluation of the breeding material so essential in the crop improvement work.

The study was started at Simla in 1951. The weather, elevation, soil aspect and other ecological conditions obtaining within a single square-mile of area in these hills being highly variable, it was thought worthwhile to collect some basic information with regard to the problems of wheat plant development for success in such an enterprise.

No published results of the wheat varieties × sowing dates trials studies in the north Indian hills are available for review of the literature on the subject. The published studies on the subject carried out in the Indian plains, having been invariably conducted by the agronomists independently (of the wheat breeders), do not bring out the importance of the varieties, known to possess well-marked differences in time of maturity, when sown on different dates of sowing. The subject is, therefore, worthy of future intensive studies in the country in order to successfully search for all the available means for increasing food production.

MATERIAL AND METHODS

Three varieties of wheat viz., NP 792, NP 770 and W 329/S.785 which differed in their maturity periods (requiring 105, 125 and 156 days respectively from seeding to ripening) were periodically sown according to the existing practices, invariably at ten days intervals in an experiment with four replications using split-plot design lay out. Sowing dates were kept as the main effects. The experiment, which was started during 1951-52 with a plot-size of 2·25 ft. × 5·00 ft., was repeated during the ensuing two years too. Besides the data of individual plot grain-yields, observations on a number of other plant characters such as per plant yield, tillering, height, stem-diameter, number of days required from sowing to earing, ear-length, number of

spikelets per ear, number of grains per ear, 1000 grain weight, number of nodes and leaf size etc., were recorded on ten representative plants selected at random in each sub-plot. Variance analyses and appropriate errors were used for testing the significance of differences in the main effects, sub-treatments and interactions. The three-year data of yield only are reported in this paper. The pooled data of the three seasons were also statistically analysed for study of the variable effects. The information on the other plant characters will be reported later.

The growth of the plant and its other characteristics are materially influenced by the weather conditions—the irregularities in the recurrence of which, induce baffling difficulties in the matter of interpretation of the results. It was, however, fortunate that the weather factors prevailing during the three seasons of this study were representative of the normal conditions prevailing at Simla. Naturally occurring fluctuations expected in the climatic complex of a place (Table I) were noticed. No serious disease epidemics were experienced in any of the three years during which this study had lasted.

TABLE I. SUMMARY OF THE ANNUAL PRECIPITATION AND EXPERIMENTAL YIELD DATA AT SIMLA DURING THE WHEAT GROWING SEASONS OF 1951-52, 1952-53, 1953-54

Year	Rainfall during the presowing month (inches)	Precipitation in inches during the month								Total during the wheat growing period	Mean yield of wheat plot (oz.) in the expt.	Rust incidence
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May			
1951–52	7·54	Traces	2·40	0·08	1·97	2·80	3·75	1·52	1·74	14·26	23·75	Traces to light
1952–53	1·10	0·09	Traces	1·09	2·70	1·45	0·00	1·81	0·93	8·07	15·38	Traces
1953–54	4·55	Traces	0·00	0·39	5·42	8·10	2·26	0·01	1·18	17·36	21·80	Traces
Normals for Simla	16·68	1·18	0·52	1·24	2·61	2·92	2·36	1·81	2·53	15·17		

NOTE: The data of the rainfall were recorded at the Potato Breeding Sub-station of the Central Potato Research Institute, Simla.

The wheat crop in the north Indian hills is almost entirely rainfed and the weather is normally very dry—particularly, during the fall and early winter. Of all the ecological factors, the rainfall and its distribution during the wheat growing season is the most potent factor determining yields. From the data summarised in Table I, it will be observed that lowest yields were recorded during 1952-53 when there was only 8·07 inches of precipitation. Somewhat satisfactory pre-sowing, late winter and early summer moisture conditions prevailing during 1951-52 and 1953-54, however, resulted in higher mean yields per plot. Slightly better yields during 1951-52 were probably due to higher moisture reserves during the pre-sowing period coupled with well spread-out rainfall during the growing season.

EXPERIMENTAL RESULTS

The experimental yield data of the three varieties × sowing dates trials are summarised in Tables II(a), III(a), IV(a) and their respective analysis of variance results are summarised in Tables II(b), III(b) and IV(b).

TABLE II(a). GRAIN-YIELD DATA OF THE THREE WHEAT VARIETIES SOWN ON DIFFERENT SOWING DATES IN THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1951-52

Varieties	Varietal yields (in oz.) on different sowing dates								
	2/10/51	12/10	23/10	31/10	10/11	20/11	30/11	11/12	Mean
N.P. 792 (Early)	17·37	20·14	19·42	22·61	23·64	28·57	29·09	17·67	22·31
N.P.770(M.late)	25·89	38·84	26·93	26·00	26·63	23·95	26·94	15·52	26·34
W329/S·785(late)	34·64	28·30	20·65	18·18	21·48	17·88	27·13	12·64	22·61
Means (S.D.)	25·97	29·09	22·33	22·26	23·92	23·47	27·72	15·28	23·75

TABLE II(b). ANALYSIS OF VARIANCE OF THE GRAIN-YIELD DATA OF THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1951-52

Sources of variation	D.F.	Total S.S.	M.S.	F.
Replications	3	16·03	5·34	
Sowing dates	7	94·01	13·43	2·96*
Error (a)	21	95·12	4·53	
Varieties	2	20·11	10·05	3·88*
Vars. × S. dates	14	98·53	7·04	2·72†
Error (b)	48	124·38	2·59	
Total	95	448·18		

*denotes significance at 5 per cent level.
†denotes significance at 1 per cent level.

Least Sig. difference between two sowing dates means at 5 per cent level : 1·81
Least Sig. difference between two varieties means at 5 per cent level : 0·81
Least Sig. difference between two varieties means of a sowing date at 5 per cent level : 2·29
Least Sig. difference between two sowing dates means of a variety at 5 per cent level : 2·59

TABLE III(a). GRAIN-YIELD DATA OF THE THREE WHEAT VARIETIES SOWN ON DIFFERENT SOWING DATES IN THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1952-53

Varieties	Varietal yields (in oz.) on different sowing dates								
	1/10/52	11/10	21/10	31/10	11/11	21/11	2/12	11/12	Means
NP. 792 (Early)	15·00	14·50	15·00	15·50	14·00	19·00	11·50	10·25	14·34
NP. 770(M. late)	18·75	18·50	23·50	24·00	16·50	17·00	11·75	10·00	17·50
W.329/S.785 (late)	26·75	18·50	19·25	14·50	12·00	9·25	7·25	7·00	14·31
Means (S.D.)	20·16	17·16	19·25	18·00	14·16	15·08	10·16	9·08	15·38

TABLE III(b). ANALYSIS OF VARIANCE OF THE GRAIN-YIELD DATA OF THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1952-53

Source of variation	D.F.	Total S.S.	M.S.	F.
Replications	3	57·44	19·15	2·67
Sowing dates	7	86·85	12·41	1·73N.S.
Error (a)	21	150·79	7·18	
Varieties	2	13·42	6·71	5·78*
Vars. × S. dates	14	50·55	3·61	3·11†
Error (b)	48	55·61	1·16	
Total	95	414·67		

* denotes significance at 5 per cent level.
† denotes significance at 1 per cent level.

Least Sig. difference between two sowing dates means at 5 per cent level : 2·27
Least Sig. difference between two varieties means at 5 per cent level : 0·55
Least Sig. difference between two varieties of a sowing date at 5 per cent level : 1·53
Least Sig. difference between two sowing dates of a variety at 5 per cent level : 2·60

TABLE IV(a). GRAIN-YIELD DATA OF THE THREE WHEAT VARIETIES SOWN ON DIFFERENT SOWING DATES IN THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1953-54

Varieties	Varietal yields (in oz.) on different sowing dates								
	1/10/53	11/10	21/10	31/10	11/11	21/11	2/12	11/12	Means
NP. 792 (Early)	20·72	27·80	27·29	24·71	25·59	21·38	28·28	16·74	24·07
NP. 770 (M. late)	27·49	25·33	27·80	24·50	22·36	15·75	23·88	19·65	23·34
W329/S.785 (late)	29·10	22·77	27·17	16·02	14·30	11·95	13·16	9·55	18·00
Means (S.D.)	25·77	25·30	27·42	21·74	20·75	16·36	21·77	15·31	21·80

TABLE IV(b). ANALYSIS OF VARIANCE OF THE GRAIN-YIELD DATA OF THE VARIETIES × SOWING DATES EXPERIMENT CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1953-54

Sources of variation	D.F.	Total S.S.	M.S.	F.
Replications	3	39·55	13·18	
Sowing-dates	7	99·28	14·18	2·35*
Error (a)	21	126·55	6·03	
Varieties	2	43·87	21·94	16·16†
Vars. × S. dates	14	53·44	3·82	2·81†
Error (b)‡	46	62·40	1·36	
Total	93	425·09		

* denotes significance at 5 per cent level.
† denotes significance at 1 per cent level.
‡ two missing plots.

Least Sig. difference between two sowing dates means at 5 per cent level : 2·08
Least Sig. difference between two varieties means at 5 per cent level : 0·57
Least Sig. difference between two varieties of a sowing date at 5 per cent level : 1·61
Least Sig. difference between two sowing dates of a variety at 5 per cent level : 2·49

It will be observed that the three varieties, which differed as regards their maturity and time of earing, differed significantly from one another as regards their yielding abilities during each of the three seasons. The different sowing dates of each variety too invariably showed significant differences during each of the three seasons.

On an average, NP. 770 (medium-late in maturity) recorded an higher average yield during the three seasons and was followed by NP. 792 (early maturing) while, W329/S.785 (late maturing) came next. As regards its over-all yield performance, W329/S.785 was almost equal to NP. 792 during 1951-52 and 1952-53. In general, the early maturing variety (NP. 792) did particularly well when sown after about the middle of October and up to about the end of November. The late maturing variety yielded the highest, during each of the three seasons, when sown on the earliest possible sowing date (i.e., very early in October). The 26-9-1951 sowing date of W329/S.785 (data not given in Table II (a)) yielded the highest of all the varieties sown on any other date during 1951-52 season. The subsequent sowings with this variety gave lower yields. The medium late ripening wheat viz., NP. 770 showed the widest range in its successful adaptability to the advancing dates of sowing after the first of October during each of the three seasons. It, therefore, follows that whereas, early variety was suitable for medium to late sowing dates, the medium late variety was on the whole most suited single variety to the conditions of varying sowing dates. The late variety, though capable of giving the highest yields when sown early in October, had the least adaptability to the advancing sowing dates and was quite unsuitable for later sowings.

Important inferences which have considerable bearing on the production as well as wheat-breeding procedures can, therefore, be derived from these observations. For maximum productivity, the late maturing varieties are the best and should be invariably sown as early in the fall as possible. When this is not possible due to the summer rains continuing up to October or due to the lack of irrigation facilities (if rains stop early in September) etc., medium-late maturing varieties are most suited for the sowings done during middle of October to the middle of November. The early maturing varieties, though not expected to do best during the early and timely sown conditions, are the best yielding sorts when the sowings have to be delayed up to the end of November or later.

The results also indicate the existence of significant differences between the different sowing dates during the seasons inspite of the somewhat equalising effects (on some sowing-date yields) due to the presence of one early and another late maturing varieties in the experiments which happened to compensate each other in yields. The earliest sowing (very early in October) gave best results during each of the three seasons. This was due to the very superior performance of the late-maturing variety. In general, the best sowing period, though differing with the variety, lasted only up to about the middle or end of November.

Whereas, the general trends of yield performance of each of the varieties included in the experiment are quite obvious, a few cases of sporadic type of variation in varietal yields with the advancing sowing dates are noticeable from the data of the individual seasons. Most of this fluctuating type of variation observed was most probably ascribable to the intermittent nature of the important environmental factor

viz., rain, which appeared to show a particularly favourable effect on the germination, and early growth of the sowings made on the dates immediately following the light showers of rain received during the sowing season. Most of this observed irregularity in some of the yield figures of the varieties during the individual seasons, however, will be seen to have been levelled-off in the combined data summarised in Table V(a).

Pooled results of the yield data of the three experiments, each with eight sowing dates (as the main-plots treatments) and three varieties (as the sub-plots treatments), conducted during each of the three years viz., 1951, 1952-53 and 1953-54 respectively are summarised in Table V(a) and their analysis of variance is given in Table V(b).

TABLE V(a). THREE YEARS' COMBINED DATA OF VARIETAL YIELDS ON DIFFERENT SOWING DATES (IN OZ.) OBTAINED FROM THE THREE SOWING DATES × VARIETIES TRIALS CONDUCTED AT THE WHEAT BREEDING SUBSTATION, SIMLA, DURING 1951-52 to 1953-54

Varieties	Combined (three years) varietal yields (in oz.) of diff. sowing dates									
	1/10	11/10	21/10	31/10	11/11	21/11	2/12	11/12	Total	Mean
NP.792	53·09	62·44	61·71	62·82	63·23	68·95	68·87	44·66	485·77	60·72
NP.770	72·13	82·67	78·23	74·50	65·49	56·70	62·57	45·17	537·46	67·18
W329/S.785	90·49	69·57	67·67	48·70	47·78	39·08	47·54	29·19	440·02	55·00
Total	215·71	214·68	207·61	186·02	176·50	164·73	178·98	119·02	1463·25	
Mean	71·90	71·56	69·20	62·00	58·83	54·91	59·66	39·67		

The pooled data show that the three seasons differed from one another significantly as regards their effects on varietal performance. The significant nature of the sowing date differences, as observed during the individual years were again observed to be highly significant for the combined data too. On the whole, beginning of October to about the later part of October was the best sowing time. The significant varietal differences observed during each of the individual seasons, however, did not appear to maintain their significance as seen in the pooled data analysis when the Varieties Mean Square is compared with Varieties × Years. M. S. (with only four degrees of freedom) as error. This test being very insensitive, the varieties M. S. was compared with the Pooled Error (b) M. S., as error. This revealed highly significant over-all differences amongst the varieties in the pooled data. Of the three varieties, NP. 770 was the best single variety on the whole and showed wider adaptability to varying sowing dates conditions. It gave best performance when sown during the 10th October to middle of November. On an average, NP. 792 was the next best variety and did particularly well when sown during 10th of October to the end of November. W329/S.785 was the highest yielder of all the varieties but only when sown very early in October. It abruptly fell-off in its performance after that date. The significant Varieties × Years and Varieties × Sowing dates interactions in the pooled data analysis deserve attention—whereas, the Sowing dates ×

Years interaction failed to show significance i.e., the different sowing dates showed similar effect during each of the three seasons.

TABLE V(b). ANALYSIS OF VARIANCE OF THE THREE YEARS' COMBINED DATA OF THE SOWING DATES × VARIETIES TRIALS CONDUCTED AT THE WHEAT BREEDING SUB-STATION, SIMLA, DURING 1951-52 TO 1953-54

Sources	D.F.	S.S.	M.S.	F.	Remarks
Replications	9	113·02	12·56		
Years	2	230·53	115·26	19·47†	
Sowing dates	7	199·37	28·48	4·88†	
Year × Sowing dates	14	82·88	5·92	1·00	N.S.
Pooled error (a)	63	372·06	5·91		
Varieties	2	49·52	24·76	3·71 14·56†	with error as 6·68 with error as 1·70
Varieties × Years	4	26·73	6·68	3·65*	
Varieties × Sowing dates	14	152·53	10·90	5·96†	
Varieties × S. dates × Years	28	51·13	1·83	1·08	N.S.
Pooled error (b)	142‡	241·98	1·70		

* denotes significance at 5 per cent level.
† denotes significance at 1 per cent level.
‡ two missing plot values.

Least Sig. difference between two varieties means at 5 per cent level : 0·37
Least Sig. difference between two Sowing date means at 5 per cent level : 1·23
Least Sig. difference between two varieties of a sowing date at 5 per cent level : 1·13
Least Sig. difference between two sowing dates of a variety at 5 per cent level : 1·44

DISCUSSION

The experimental results point to the vital importance of the choice of suitable varieties (as regards their time of maturity) depending upon the considerations of available sowing time from the point of view of increasing production of wheat per acre in the hills. Longer growing season results in higher production is too well known a fact [Laude, 1938]. Highly significant nature of the Varieties × Sowing dates interaction has been repeatedly observed from the results of similar experiments arranged at different stations in the Himachal Pradesh using larger plot-sizes and greater number of replications.

It is, however, quite likely that very late or medium-late maturing varieties may not quite fit in with the available wheat growing seasons in the Indian plains but, the good yield performance of Pb. C. 591 [Anant *et al.*, 1957], Ridley and some other fairly late maturing varieties even in the eastern parts of the Indo-Gangetic plains and Rajasthan have been quite often reported. Though deliberately designed Sowing-date × Varieties experiments using wheat varieties with known differences in their maturity periods have yet to be conducted in the different parts of the country, we are

perhaps not justified in declaring that the practice may not have a fairly wide application for some of our wheat growing areas with comparatively shorter growing periods than that prevailing in the hills. It is, however, highly likely that the practice of sowing comparatively late-maturing varieties fairly early in October will give increased production in the Punjab and other north-western regions where a longer growing season is assured.

Though the date of sowing has been observed to be a very potent ecological factor for increasing wheat yields, particularly in the hills, the experimental data is also suggestive of our making slight modifications in our existing wheat breeding and varietal testing procedures in the interest of an accurate evaluation of the genetic material in our plant breeding experiments. It is thought that the wheat breeders should make available to our farmers a set of at least two or more varieties of varying maturity periods in order to enable them to produce more per acre. In the Punjab, Pb. C. 228 used to be recommended for only late sowings. That the farmer should multiply two varieties different in their maturity periods, each year, appears to be a desirable regular practice. At our breeding stations, the selection from the genetic material should perhaps be based on our giving proper importance to the requirements of the tract as regards the varietal maturity.

The varietal testing work, which is quite time consuming, could perhaps be considerably simplified and rendered more accurate by staggering part of the replications of each test by sowing them at regular intervals during the available sowing time. For example, if the wheat sowings are normally practised during middle of October to middle of November, two of the required six replications of a simple randomized blocks lay-out experiment may be sown on October 15 followed by another two each on the 31st October and 15th November. The procedure will respond to the elimination of the fluctuations in yield resulting from the sowing date factor by separating out the sowing dates contribution from the experimental-error without in any way adding to the experimental work involved. The procedure will also partly help in ironing out the frequently observed year to year fluctuations in the performance of a variety at any place due to the differential response of varieties under the conditions of varying sowing dates. Whereas, the recommended experimental procedure does not suffer from any practical or statistical analysis objections required for sound experimentation, it is certainly to be preferred to separate Sowing dates $\times$ Varieties experiments which need additional resources that are not always available at an experiment station. Moreover, the adoption of the procedure will enable the correct evaluation of the breeding material fairly early in the process of varietal evolution, as consistent results of varietal performance should reduce the time required for testing of the new types. This will also result in the utilization of types which show appreciable differential response to particular sowing dates and are subject to the risk of being discarded out under our methods of testing now in vogue.

The conventional procedures are invariably impracticable when a large number of varieties are to be evaluated. The recommended procedure is expected to be of value in the testing of other crop-plant varieties besides the wheat and other *rabi* food grains, particularly, under the conditions when the season is not the limiting factor for the maturity of long growing season varieties.

SUMMARY

The experiments with early, medium-late and late maturing varieties of wheat sown at regular periodic intervals have shown the presence of highly significant differences among the varieties, sowing dates and their interaction.

The three varieties used, widely differed in their adaptability to early, medium and late sowings. Whereas, the early maturing variety was the best under late-sowing conditions, the medium-late maturing variety showed a wider degree of adaptability to the varying dates of sowing and the late-maturing variety was the highest yielder, only when sown very early in October. Accordingly, for maximum productivity, whenever and wherever early sowings can be practised, these should be done with late-maturing varieties, medium-late sowings with medium-late-ripening ones and the late-sowings should be done with early maturing varieties.

Based on these results, it is suggested that the plant breeders should make available to the farmers, varieties differing in their maturity periods as also the requisite information regarding their suitability for the changing sowing-date conditions in order to increase the country's food production.

In view of the sowing dates being a very important factor of wheat production, the sowing of a part of the different replications of a randomized blocks lay-out test should be spread over the entire sowing period of the locality at regular intervals. The practice is expected to make the varietal testing technique more precise without in any way adding to the quantity of work involved. The adoption of such a procedure at a breeding station enjoys definite advantages over the conventional practice of laying out separate Sowing dates × Varieties trials with the varieties made available by the breeders.

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BIOCHEMICAL STUDIES ON THE ACTIVITY OF ACID PHOSPHATASE, ALKALINE PHOSPHATASE AND PHOSPHORYLASE ON *CICER ARIETINUM* AFTER INDUCTION OF POLYPLOIDY BY COLCHICINE—I

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As in other biological processes, different phases of mitosis and meiosis, which lead to the synthesis of nucleo-proteins, duplication of chromosomes and division of the nucleus, are the results of chemical reactions controlled by a chain of enzyme systems in different phases. It is likely that if any disturbance is brought about in the enzyme system, the normal mitotic phases might be interfered with. It was, therefore, thought that the study of the activity of different enzymes at various stages of polyploidisation of seeds by treatment with colchicine, might throw some light in our understanding of the mechanism of this process.

The importance of the phosphate bond in plant biochemistry, as well as energy yielding mechanism in plants, is well established. Bose *et al.* [1957], reported on the inhibitory effect of colchicine treatment on the dehydrogenase system in *Cicer arietinum*. It was, therefore, considered advisable to extend the scope of this work on other enzymes viz., acid and alkaline phosphatase, as well as phosphorylase, during the process of polyploidisation in these seeds. The results of these investigations are contained in the present paper.

EXPERIMENTAL METHODS

Technique of Germination and Induction of Polyploidisation

The technique of germination followed in the present investigation, has been the same as reported previously (*loc. cit.*).

Five grams of seeds in each batch were divided into two sets, one being germinated in distilled water and used as control, while the other was treated with 0·08 per cent colchicine solution for 24 hours to induce polyploidy before germination. After every 24 hours of germination, a certain quantity of seeds from each set was taken out, homogenised in Waring Blendor with distilled water and filtered. The filtrate was used for enzymatic study.

Estimation of acid and alkaline phosphatase activity: The activities of acid and alkaline phosphatase enzymes were determined by the method of Bodansky [1933] as detailed below:

To 10 ml. of the substrates (alkaline sodium β-glycerophosphate of pH 9 for alkaline phosphatase and acid glycerophosphate of pH 5 for acid phosphatase) at 37°C., 1 ml. of the above enzyme extract was added and incubated for one hour. After the mixture was cooled, 3 ml. of 30 per cent trichloracetic acid was added for inhibiting enzyme activity and precipitating the proteins. The filtrate was analysed

for total inorganic phosphorus by using ammonium molybdate and ∝-amino-naphthol sulphonic acid, according to the method of Fiske and Subbarrow [1925]. Parallel blanks were run in which trichloracetic acid was added before incubation. The difference between the phosphorus content of the two sets gave the measure of the enzymatic activity, expressed in terms of Bodansky Unit.

TABLE I. *ACID PHOSPHATASE CONTENT OF DIFFERENT PARTS OF COLCHICINE TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine treated group			Control group		
	Whole seed	Cotyledon	Growing parts	Whole seed	Cotyledon	Growing parts
1×24	107·1	..	..	97·0	..	..
2×24	166·3	154·1	1,375·0	295·0	283·0	8,152·0
3×24	190·3	100·3	2,400·0	347·0	252·4	9,667·0
4×24	196·0	78·0	2,954·0	361·0	117·0	3,492·0
5×24	294·0	52·0	2,000·0	412·0	101·0	3,434·0
6×24	178·0	40·3	1,200·0	368·0	94·0	2,000·0
7×24	55·0	35·0	700·0	294·0	80·0	1,367·0

* The values are expressed as Bodansky Unit/100 gm. of dry seeds.

It will be seen from Table I, that the acid phosphatase activity differed considerably in the two sets of experiments. In the control set of diploids, the acid phosphatase activity in whole seeds, cotyledons and the growing parts, started increasing from the first day onwards, reaching their maximum of 412·0, 283·0 and 9,667·0 Bodansky Unit on the fifth, second and third day respectively. Thereafter there was a decline. In the test set of colchicine-treated seeds, in which polyploidisation had already occurred, the acid phosphatase activity reached its maximum of 294·0, 154·0 and 2,954·0 Units on fifth, second and fourth day respectively, after which there was a decline.

It is, however, significant that in all the parts of seeds, as detailed in Table I, the phosphatase activity was markedly less in the case of the colchicine-treated group, as compared to the control set, which clearly suggests that there is relative inhibition of the enzyme activity during the process of polyploidisation.

An analysis of Table II indicates that there was a gradual increase in the enzyme activity up to the fourth day in the whole seed and cotyledon and on the second day, in the case of growing parts in the control set of seeds. Thereafter, there was a decline. In the colchicine-treated seeds, the maximum activity was found to be 4·6, 1·5 and 154·0 Units on the fifth, third and fifth day respectively in the whole seeds, cotyledon and growing parts and thereafter there was a fall in this case also. Comparison of results of growing parts revealed that the enzymatic activity was more marked in the case of diploids than in polyploids indicating thereby the possibility of the inhibiting effect of colchicine on the activity of this enzyme.

TABLE II. *ALKALINE PHOSPHATASE CONTENT OF DIFFERENT PARTS OF COLCHICINE-TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine-treated group			Control group		
	Whole seed	Cotyledon	Growing parts	Whole seed	Cotyledon	Growing parts
1×24	1·4	..	..	0·63	..	..
2×24	2·7	0·5	100·0	2·5	0·5	300·0
3×24	3·0	1·5	120·0	2·7	0·5	210·0
4×24	4·0	1·0	130·0	3·2	1·7	110·0
5×24	4·6	1·1	154·0	1·4	0·7	80·0
6×24	3·0	1·0	64·0	1·2	0·5	70·0
7×24	2·7	0·9	90·0	1·1	0·2	80·0

* The values are expressed in Bodansky Unit/100 gm. of dry seeds.

Estimation of phosphorylase activity: This was determined by the modified method of Cori *et al.* [1943], and Green and Stumpf [1942].

A digest was prepared by taking 1 ml. of citrate buffer (*p*H 6), 2 ml. of 1 per cent soluble starch and 1 ml. of 0·064M glucose-1-phosphate. It was brought to 37°C. before adding 1 ml. of properly diluted enzyme preparation (1:1,000) and incubated exactly for five minutes. The reaction was stopped by adding 0·5 ml. of trichloracetic acid and the solution was filtered. The filtrate was analysed by the same method as was followed for the estimation of phosphatase activity. A blank was run in which trichloracetic acid was added at the zero time. Difference between the two values, represented the quantity of inorganic phosphorus liberated by the phosphorylase activity in the different parts of seeds. The values obtained are expressed in terms of Green and Stumpf Unit, which is based on the liberation of 0·1 mg. of inorganic phosphorus from the above substrate, at a temperature of 37°C. at *p*H 6 within five minutes. The results are presented in Table III.

TABLE III. *PHOSPHORYLASE CONTENT OF DIFFERENT PARTS OF SEEDS OF COLCHICINE-TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine-treated group			Control group		
	Whole seed	Cotyledon	Growing parts	Whole seed	Cotyledon	Growing parts
1×24	1,285	..	..	942	..	..
2×24	1,666	420	1,25,000	4,156	844	2,20,000
3×24	2,513	1,526	1,60,000	9,173	3,160	2,37,250
4×24	2,577	1,601	20,000	8,237	2,216	18,000
5×24	2,617	1,680	16,000	2,247	1,830	7,143
6×24	1,760	1,470	5,000	1,866	1,552	3,774
7×24	833	900	4,300	1,250	1,000	2,500

* The values are expressed in green and stumpf units/100 gm. of dry seeds.

From an analysis of the above observations, it is evident that in both diploids and polyploids, there was a gradual increase in the activity up to the fourth day (9,173 Units) in the case of the diploid, fifth day (2,617 Units) in the case of the polyploid and after that there was decline like other enzymes. While surveying the results of the growing parts, it would appear that in both diploids and polyploids, there was a large amount of activity stored in these regions and this activity reached its maximum in the third day after which it gradually declined and on the seventh day, it reached to a very low value, as compared to the initial value on the second day. This decrease in the enzymatic activity in the growing parts, might suggest that the enzyme was probably utilized for the synthesis of the starch.

DISCUSSION

From the present study, it is apparent that of the three enzymes under investigation, acid phosphatase, and phosphorylase activity have been markedly inhibited in the growing parts of the germinating seeds namely radicle and plumule after colchicine treatment. Though it is difficult to assess the actual cause of such an inhibition, it is possible that colchicine might produce the above disturbance by inhibition of the rate of synthesis, partial destruction or by higher utilization of the enzyme during the process of polyploidisation. Acid phosphatase and phosphorylase, involved in the synthesis of starch from the stage of hexose onwards, are essentially required for the growth of the plant. It is likely that colchicine, by inhibiting the rate of synthesis of these enzymes, might suppress the growth of the radicle and plumule.

SUMMARY AND CONCLUSION

In the present investigation, the effect of colchicine treatment on the activity of acid and alkaline phosphatase as well as phosphorylase during germination of *Cicer arietinum*, has been studied.

In all the three cases, the growing parts of colchicine-treated seeds, showed a marked inhibition in the enzymatic activity, particularly of acid phosphatase and phosphorylase, as compared to the untreated diploid seeds.

The probable significance of the reduction of activity of the above two enzymes, during the process of polyploidisation has been discussed.

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BIOCHEMICAL STUDIES ON THE ACTIVITY OF PEROXIDASE AND CATALASE ON *CICER ARIETINUM* LINN. AFTER INDUCTION OF POLYPLOIDY BY COLCHICINE—II

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Oxidase group of enzymes catalyses the oxidation of phenol as well as closely related compounds. They also help in the breakdown of toxic hydrogen peroxide in animal and plant cells. Peroxidase is considered important for the former type of reaction, whereas catalase prevents the accumulations of hydrogen peroxide in the cell. Actively growing plant tissues exhibit a high rate of respiration as well as high catalase activity. It is, therefore, likely that during the process of polyploidisation, this group of enzymes plays an important role so far as the growth of the active plant tissues is concerned.

In previous communications [Bose *et al.*, 1957, 1958], the effects of colchicine treatment on dehydrogenase and phosphorylase enzyme as well as phosphatase activities during the process of polyploidisation have been reported. In the present study, the activity of peroxidase and catalase enzymes in the growing seedlings of *Cicer arietinum*, after induction of polyploidy by colchicine, has been investigated.

EXPERIMENTAL METHODS

The technique of germination, followed in the present investigation, has been the same as reported previously (*loc. cit.*). Control, as well as colchicine treated test samples up to the seventh day of germination were homogenised with distilled water, and filtered. The filtrate was then used for enzymatic study

Estimation of Peroxidase Activity

This was measured according to the method of Axelrod and Jagendorf [1951]. In this method, time required for a decrease in optical transmission of a standard reaction mixture from 100 to 90 was noted and calculated into units which were arbitrarily considered to be equal to the reciprocal seconds divided by ml. of the preparation, used in the test.

The reaction mixture was prepared by taking 7 ml. of water, 0·5 ml. of 1 M acetate buffer of *p*H 5, 1 ml. of 1 per cent v/v aqueous guaicol and 1 ml. of diluted extract (1 : 1,000), added and thoroughly mixed. With this mixture, the galvanometer was set to 100. One millilitre of 0·97 per cent hydrogen peroxide was then added and the time in seconds for the deflection of the galvanometer needle to 90 from 100 was noted. The reaction was carried out at 25°C. The values are presented in Table I.

TABLE I. *PEROXIDASE ACTIVITY OF DIFFERENT PARTS OF COLCHICINE TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination in hours	Colchicine-treated group			Control group		
	Whole seed	Cotyledon	Growing parts	Whole seed	Cotyledon	Growing parts
1×24	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
2×24	–do–	–do–	–do–	481·0	132·0	12,200·0
3×24	200·0	–do–	3,205·0	1,066·0	168·0	1,48,500·0
4×24	230·0	–do–	3,246.0	1,340·0	409·0	15,426·0
5×24	600·0	386·0	3,555·0	1,344·0	1,206·0	5,466·0
6×24	1,350·0	557·0	12,307·0	1,792·0	1,363·0	4,081·0
7×24	2,659·0	1,960·0	9,264·0	2,702·0	2,014·0	3,277·0

* The values are expressed as units/100 gm. of dry seeds.

On analysis of Table I, it will be seen that peroxidase activity has constantly been on the increase up to the seventh day of germination in both diploids and polyploids, reaching the maximum of 2,702·0 and 2,659·0 units respectively, whereas in the growing parts of control seeds, the maximum activity (1,48,500 units) has been on the third day after which there has been a prompt and substantial decline in the peroxidase activity. In colchicine-treated seeds it may be noted, there has been maximum increase in peroxidase activity (12,307 units) on the sixth day of germination. The cotyledons of both the groups of seeds have shown comparatively less activity in the early days of germination, reaching the maximum of 1,960 units in polyploids and 2,014·0 units in diploids on the seventh day of germination. The results obtained with diploids and polyploids indicate that the peroxidase activity has been slightly more in the control than in the colchicine treated seeds.

Estimation of Catalase Activity

It was measured according to the A.O.A.C. 1950 method as detailed below:

To 42 ml. of distilled water, 1 ml. of the enzyme extract (1 : 100), 5 ml. of buffered dextrose solution and 2 ml. of 0·1 N hydrogen peroxide were added and 10 ml. aliquot of the above reaction mixture immediately (zero time) removed to a flask containing sulphuric acid molybdate solution. Similarly, five and ten minutes time reaction aliquots were also taken. To each flask, standard sodium thiosulphate solution was added and back titrated with iodine solution. A blank was run without adding hydrogen peroxide. The results calculated as per A.O.A.C. method, are shown in Table II.

From the examination of Table II, it will be seen that the enzymatic activity gradually increased to a maximum of 760 units in colchicine-treated seeds and 540 units in the control group on the sixth and fifth days of germination respectively, after which there was decline in both the cases. Similar increase was noticed in the case of cotyledons in both diploids and polyploids. While comparing the results of

growing parts, colchicine-treated seeds showed maximum activity of 6,072 units on the fourth day but in the case of control group of seeds, the maximum of 2,532 units was observed on the fifth day of germination after which there was a gradual fall in both the cases. The results obtained with diploids and polyploids show that the catalase activity was more in all the parts of polyploids than in control seeds.

TABLE II. *CATALASE CONTENT OF DIFFERENT PARTS OF COLCHICINE TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination in hours	Colchicine-treated group			Control group		
	Whole seed	Cotyledon	Growing parts	Whole seed	Cotyledon	Growing parts
1×24	108·0	..	..	186·0	..	..
2×24	111·0	110·0	210·0	210·0	180·0	235·0
3×24	180·0	154·0	2,160·0	293·0	258·0	1,243·0
4×24	379·0	311·0	6,072·0	400·0	320·0	1,600·0
5×24	530·0	450·0	2,188·0	540·0	370·0	2,532·0
6×24	760·0	690·0	1,841·0	510·0	320·0	1,664·0
7×24	540·0	500·0	1,220·0	420·0	280·0	1,120·0

*The values are expressed as units/100 gm. of dry seeds.

SUMMARY AND CONCLUSION

During the present study on the effect of induction of polyploidy by colchicine on the activity of peroxidase in the growing seedlings of *Cicer arietinum* a decrease in activity in polyploids has been observed. This may be due to one of the following factors:

(i) Relative paucity of epidermal and endodermal cells in polyploids, in which the peroxidase activity is normally located.

(ii) Greater utilization of peroxidase during the process of polyploidisation.

Work on the catalase activity in polyploids, as carried out in the present investigation, has shown that there is a quantitative increase of this enzyme during the process of polyploidisation. From the above, it would appear that catalase plays a different role from dehydrogenase and phosphorylase systems, which as has been reported in a previous communication (*loc. cit.*), are inhibited, whereas the catalase activity is enhanced during polyploidisation.

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BIOCHEMICAL STUDIES ON THE ACTIVITY OF AMYLASE AND ESTRASE ON *CICER ARIETINUM* LINN. AFTER INDUCTION OF POLYPLOIDY BY COLCHICINE—III

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Amylase is responsible for the conversion of reserve carbohydrate in plants to sugars in soluble form, which can be transported for further utilization. It has been observed that non-germinated seeds generally contain only traces of amylase, whereas during the process of germination of grains, a large amount of this enzyme is either formed or set free from inactive complexes. Estrase group of enzymes catalyses the reversible reaction of hydrolysis of esters. A number of estrases exist in plant and animal cells, some of which are specific like *cholinestrase*. Other estrases, though non-specific, are also effective in the breakdown of esters.

During the early stage of germination, when stored carbohydrate is required to be transported to the growing regions, it is possible that the amylase group of enzymes plays an important role in the process of induction of polyploidisation. The effect on the activity of the enzyme might ultimately result in the growth of the seedlings. The content of simple estrases could also be affected during the process of polyploidisation.

In earlier communications, Bose *et al.* [1957, 1959] reported on the effect of polyploidisation on dehydrogenase, phosphatase, phosphorylase, catalase and peroxidase enzyme systems. It was observed that some of these enzymes like catalase are stimulated whereas others depressed. The present paper embodies the observations on the activity of amylase and simple estrases during the process of polyploidisation.

EXPERIMENTAL METHOD

The technique of germination and preparation of the enzymatic extract, followed in the present investigation has been the same as reported previously (*loc. cit.*).

Amylase activity: A.O.A.C. [1950] method for the estimation of diastatic power of malt was used with modification as detailed below:

Germinated seedlings of 5 gm. of seeds were ground in Waring Blendor with distilled water and made into a total volume to 100 ml. It was kept at room temperature for three hours and filtered; 10 ml. of the extract were added to 100 ml. of buffered starch solution (2 per cent) and the activity stopped by adding 0·5 ml. of 0·5 N, NaOH solution. A known quantity of Fehling's solution was titrated with the above mixture, using methylene blue as an indicator. A blank was run in which NaOH solution was added to the extract before adding the starch solution. The values of amylase activity were calculated as Linter degrees. From the blank titration readings, the amount of sugar was calculated in terms of maltose.

The amylase content in control and in colchicine-treated seeds are presented in Table I. Changes in the sugar content in diploids and polyploids are shown in Table II.

TABLE I. *AMYLASE CONTENT OF DIFFERENT PARTS OF COLCHICINE TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine-treated group		Control group	
	Whole seeds	Cotyledons	Whole seeds	Cotyledons
Seeds untreated	..	..	1·80	..
24 hours soaking	2·20	..	2·13	..
1×24	2·40	..	2·38	..
2×24	2·40	2·21	2·47	2·41
3×24	2·58	2·24	2·71	2·58
4×24	2·70	2·30	4·02	3·30
5×24	2·90	2·48	3·77	3·38
6×24	3·00	2·54	3·64	3·55
7×24	3·01	2·47	5·08	3·62

* Values expressed as Linter degrees/100 gm. of dry seeds.

TABLE II. SUGAR CONTENT (IN GRAMS/100 G.) OF DRY SEEDS CALCULATED AS MALTOSE PRODUCED BY AMYLASE ACTIVITY IN COLCHICINE TREATED AND CONTROL SEEDS DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine treated group		Control group	
	Whole seeds	Cotyledons	Whole seeds	Cotyledons
Seeds untreated	..	..	1·19	..
24 hr. soaking	1·57	..	1·64	..
1×24	1·58	..	1·66	..
2×24	1·60	1·50	1·78	1·70
3×24	1·66	1·52	1·90	1·80
4×24	1·78	1·60	1·95	1·83
5×24	1·83	1·64	2·06	1·91
6×24	1·85	1·66	2·26	1·94
7×24	1·90	1·72	3·15	1·94

On analysis of Tables I and II it is evident that diploid seeds showed more activity than polyploids reaching their maximum of 5·08 and 3·01 Linter degrees on the

seventh day of germination respectively. It will, however, be seen that on the first day of germination, the enzymatic activity was more in colchicine-treated seeds. The cotyledons also showed a gradual rise in the activity. The maximum of 3·62 and 2·54 Linter of degrees activity was observed in diploids and polyploids on the seventh and sixth day of germination respectively. The sugar content also showed a similar rise in both the cases reaching the maximum of 3·15 gm. and 1·90 gm. on the seventh day of germination in diploids and polyploids respectively. It will thus be evident that the sugar formed in diploids was almost double the quantity as compared to polyploids on the seventh day.

Estrase activity: This was determined by the following method:

In a series of flasks containing 3 ml. of enzyme solution (1:20), 0·5 ml. of saturated ethyl butyrate solution was added. It was titrated to neutralization with N/100 NaOH, using 0·2 ml. of 0·1 per cent solution of phenolphthaline as indicator. To the reaction mixture, 0·2 ml. of N/100 NaOH was added and the time in minutes (T) noted for complete disappearance of phenolphthalin colour. The activity was calculated in units as (1/T.). The results are indicated in Table III.

TABLE III. *ESTRASE ACTIVITY (1/T.) DEDUCED FROM THE RECIPROCAL OF THE TIME OF DISCHARGE OF PHENOLPHTHALIN COLOUR IN MINUTES (T) IN DIFFERENT PARTS OF COLCHICINE TREATED AND CONTROL SEEDS OF *CICER ARIETINUM* DURING THE PERIOD OF GERMINATION FOR SEVEN DAYS

Period of germination (in hours)	Colchicine-treated group			Control group		
	Whole seeds	Cotyledons	Growing parts	Whole seeds	Cotyledons	Growing parts
24 hrs. soaking	3·5	..	..	3·5	..	..
1×24	4·1	..	..	3·9	..	..
2×24	4·5	4·4	6·3	5·1	4·9	9·3
3×24	5·7	5·2	10·9	5·9	5·5	10·9
4×24	5·9	5·3	12·9	6·3	5·9	11·4
5×24	6·2	5·5	15·7	6·5	5·6	16·4
6×24	6·6	5·7	16·5	6·9	5·5	17·3
7×24	6·7	5·5	17·0	7·7	5·5	17·8

* The values are expressed per 100 gm. dry seeds.

From Table I, it will be seen that the enzymatic activity in whole seeds of both diploid and polyploid groups gradually increased up to the seventh day reaching 7·7 units and 6.7 units respectively. Cotyledons also showed a similar rise but day to day content in both the cases did not show a marked difference in the activity. In growing parts, the enzymatic content was 17·8 units in control and 17·0 units in colchicine treated seeds on the seventh day indicating thereby that there was no marked difference in the activity in the two series.

SUMMARY AND CONCLUSION

In the present series of experiment, the role of amylase in the induction of polyploidisation in *Cicer arietinum* has been investigated. It has been observed that diploid seedlings show greater amylase activity with increase in sugar content as compared to the polyploids. In diploids, due to rapidity in growth, and higher rate of photosynthesis, a larger quantity of starch is formed.

This starch, for its translocation to other active parts of the plant in the form of soluble sugars, might be requiring higher content of the enzyme. In polyploid, due to its very slow unfolding of foliar regions, the process of photosynthesis proceeds at a lower rate and hence less substrate is available for the amylase activity, which ultimately results in reduced sugar content. From the above, it would appear that colchicine, due to its inhibitory action on polyploidisation and consequent reduction in growth of the seedlings, might also exercise a depressant action of the amylase activity in the seedlings.

In the present investigation, it has been observed that colchicine treatment did not materially affect the estrase content of the seedlings which, therefore, may not be envolved in the induction of polyploidisation.

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GROWTH STUDIES ON AND NUTRIENT UPTAKE BY CIGAR TOBACCO

II. THE ABSORPTION OF NUTRIENTS BY CIGAR TOBACCO AT DIFFERENT STAGES OF GROWTH*

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A study of the absorption of nutrients by the cigar tobacco plant grown in South India was undertaken to determine the period or periods in its growth cycle when the absorption of nutrients is the greatest. This information would help in formulating proper fertilizer schedules so as to supply the required nutrients to the crop at the time when their need is the greatest. Similar studies have been made by Davidson [1895], and Anderson *et al.* [1932, 1938] who studied potassium absorption by the cigar tobacco plant at different stages of growth; Morgan and Street [1935] who studied the assimilation of nitrogen by Havana seed tobacco; Grizzard *et al.* [1942] who studied the assimilation of nitrogen, potassium, phosphorus, calcium, magnesium and sulphur by flue-cured tobacco; and Parikh and Shah [1954] who studied the absorption of nutrients by the *bidi* tobacco. In the present investigation, the absorption of nitrogen, potassium, phosphorus, calcium, magnesium, sodium, sulphur and chlorine and accumulation of nicotine at weekly intervals by the leaves and stalks of cigar tobacco grown in South India have been studied.

MATERIAL AND METHODS

Details regarding the transplanting, manuring and cultural operations were given in part I of this communication [1957]. Leaf and stalk samples were collected at weekly intervals. A separate plot was assigned to each sampling date in a simple randomised block design in which four replications were provided. The stalks and leaves from each plot were dried separately in a steam oven at 95° C. and samples collected for chemical analysis.

When a leaf from a particular position on the stalk matured prior to the date of uprooting, the corresponding leaves from all the plants in the sample were primed before they turned yellow to form a separate sample for chemical analysis. Similarly, the tops removed at the time of topping and the suckers formed separate samples. All the leaf and stalk samples collected from the 4th week after transplanting up to the time of harvesting, primed leaves, tops and suckers were analysed for nitrogen, potassium, phosphorus, calcium, magnesium, sodium, sulphur, chlorine and nicotine.

N, P_2O_5, CaO, MgO, Cl and S were determined as per the methods recommended by the Association of Official Agricultural Chemists [1950]; and Na_2O and K_2O as per

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the methods recommended by Piper [1947]. Nicotine was determined in the improved steam distillation apparatus suggested by Griffith and Jeffrey [1948].

RESULTS AND DISCUSSION

Chemical composition of the leaves, stalks and the whole plant determined at weekly intervals is given in Table I. It will be seen from the Table that the total nitrogen content of the leaves decreased progressively while that of the stalks was more or less the same throughout the entire growth period. The nitrogen content of the stalks was always lower than that of the leaves. Morgan and Street [1935] in the case of Havana seed tobacco, and Parikh and Shah [1954] in the case of *bidi* tobacco observed that the nitrogen content of the leaves began to decrease 40 and 60 days respectively after transplanting, while that of the stalks decreased progressively after transplanting. Grizzard *et al.* [1942] reported a progressive decrease in the nitrogen content of flue-cured tobacco. The lower leaves of the plant, which matured and were primed before they turned yellow (leaves 4 and 5; 6 and 7; 8; 9; 10 and 11; and 12) had lower nitrogen content than that of the other green leaves which had not completely matured; on the other hand, the growing foliage (tops and suckers) were richer in nitrogen than the other green leaves. This would suggest that as a leaf matured, its nitrogen was transferred to the upper green leaves.

The potassium content of the leaves decreased steadily whereas that of the stalks was more or less the same throughout the entire growth period. Anderson *et al.* [1932] reported the same trend for Havana seed tobacco. The potassium content of the leaves was higher than that of stalks up to seven weeks after transplanting; thereafter the latter was more than the former. The potassium content of the leaves which were mature and primed before they turned yellow was same as that of the other green leaves of the corresponding sampling dates. This would therefore suggests that the potassium already accumulated in the leaf is not transferred to the upper leaves even though their potassium content is low.

Compared to nitrogen and potassium, the phosphorus content of the leaves and stalks was very low but it decreased steadily in both the leaves and stalks with increasing plant age. The phosphorus content of the leaves was slightly more than that of the stalks throughout the growth period. As in the case of nitrogen, the phosphorus content of the leaves which were mature and primed before they turned yellow was lower than that of the other green leaves of the corresponding sampling dates; this indicates that as a leaf matured its phosphorus was transferred to the upper green leaves.

The calcium content of the leaves remained more or less the same while that of the stalks increased steadily with the advancing plant age. The calcium content of the leaves was always considerably more than that of the stalks. The calcium content of the leaves, which were mature and primed before they turned yellow, was more than that of the other green leaves of the corresponding sampling dates, thus indicating that the calcium already accumulated in the leaf is not transferred to the upper leaves even though their calcium content is comparatively low. Garner [1951] has concluded that under average conditions the calcium content of the leaf is more than that of potassium whereas the calcium content of the stalk is always low regardless

TABLE I. CHEMICAL COMPOSITION OF CIGAR

(All the nutrients and nicotine expressed as

Weeks after transplanting	Date of sampling (1952–53)	Date of sampling (1953–54)	Yield of dry matter lb./acre	N		K_2O		P_2O_5	
				52–53	53–54	52–53	53–54	52–53	53–54
4	3–12–52	28–11–53	14·39	4·14	4·18	9·29	8·27	0·82	1·08
5	10–12–52	5–12–53	61·08	4·12	4·20	10·59	8·92	0·90	1·06
6	17–12–52	12–12–53	115·93	4·10	4·26	10·79	8·78	0·79	1·21
7	24–12–52	19–12–53	290·75	3·97	4·01	9·47	8·50	0·74	1·09
8	31–12–52	26–12–53	470·31	3·86	3·98	6·70	6·72	0·74	1·11
9	7– 1–53	2– 1–54	840·86	3·85	3·96	6·60	6·50	0·69	1·02
10	15– 1–53	9– 1–54	1126·62	3·10	3·95	6·43	6·24	0·56	1·04
11	22– 1–53	16– 1–54	1221·80	2·89	3·91	5·79	5·96	0·66	0·95
12	29– 1–53	23– 1–54	1254·17	2·56	3·26	4·35	4·59	0·56	0·95
13	5– 2–53	30– 1–54	1558·65	2·73	3·18	4·82	4·62	0·56	0·80
4	3–12–52	28–11–53	1·5	2·04	2·66	6·26	6·65	0·71	0·86
5	10–12–52	5–12–53	4·8	2·31	1·98	6·08	6·59	0·69	0·80
6	17–12–52	12–12–53	9·6	2·29	2·16	6·34	6·53	0·69	0·73
7	24–12–52	19–12–53	30·9	2·26	2·19	7·02	6·70	0·61	0·78
8	31–12–52	26–12–53	64·6	2·34	2·20	7·27	6·85	0·67	0·82
9	7– 1–53	2– 1–54	185·1	2·41	2·23	7·83	6·97	0·71	0·84
10	15– 1–53	9– 1–54	331·2	2·29	1·66	6·36	6·35	0·45	0·61
11	22– 1–53	16– 1–54	461·4	2·33	2·05	6·18	6·21	0·46	0·69
12	29– 1–53	23– 1–54	619·1	2·56	2·52	6·21	6·23	0·46	0·71
13	5– 2–53	30– 1–54	754·1	2·58	2·79	6·04	6·01	0·48	0·71
Leaves 4 & 5*	24–12–52	19–12–53	14·34	2·04	2·23	9·13	8·10	0·58	0·58
,, 6 & 7	7– 1–53	2– 1–54	46·56	2·04	2·16	7·48	7·24	0·49	0·51
,, 9 & 10	15– 1–53	9– 1–54	159·12	1·87	2·01	5·92	5·39	0·34	0·50
,, 11 & 12	29– 1–53	23– 1–54	155·76	1·45	1·88	5·06	5·21	0·38	0·47
Tops	15– 1–53	9– 1–54	89·95	4·40	5·49	7·67	6·95	0·32	1·26
Suckers	29– 1–53	16– 1–54	10·32	4·90	5·80	8·33	7·26	0·39	1·18

*Leaves 1, 2 and 3 were on the seedlings.

TOBACCO PLANT AT WEEKLY INTERVALS

percentage values on oven dry basis)

CaO		MgO		Na_2O		S		O		Nicotine	
52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–53‡
Leaves (uncured)											
5·47	5·61	0·82	0·92	0·19	0·18	0·36	0·27	2·21	2·16	0·31	0·29
5·36	5·69	0·91	0·95	0·19	0·18	0·36	0·28	0·44	2·32	0·43	0·46
5·57	5·63	0·96	1·31	0·19	0·19	0·38	0·28	2·42	2·57	0·51	0·55
5·37	5·92	1·04	1·23	0·17	0·17	0·43	0·29	3·10	2·61	0·52	0·46
6·01	6·02	1·14	1·28	0·17	0·19	0·42	0·30	3·18	2·61	0·51	0·49
5·84	5·41	1·22	1·52	0·17	0·16	0·43	0·43	3·42	3·53	0·52	0·55
3·96	5·36	1·20	1·49	0·17	0·19	0·42	0·40	3·69	3·69	0·71	0·76
4·78	5·76	1·14	1·51	0·16	0·19	0·38	0·40	4·21	3·61	1·51	1·41
4·86	5·61	1·09	1·21	0·14	0·17	0·48	0·36	3·67	3·76	1·64	1·42
5·31	5·62	1·01	1·38	0·13	0·15	0·49	0·34	3·37	3·58	1·66	1·46
Stalks											
1·47	1·52	0·63	0·72	0·23	0·21	0·28	0·20	1·38	1·34	0·02	0·02
1·49	1·50	0·72	0·66	0·24	0·23	0·29	0·21	1·36	1·39	0·02	0·02
1·56	1·63	0·60	0·73	0·22	0·23	0·32	0·25	1·49	1·68	0·02	0·03
1·63	1·76	0·50	0·79	0·21	0·23	0·35	0·25	1·72	1·56	0·03	0·03
1·43	1·84	0·81	0·91	0·23	0·20	0·38	0·27	1·90	1·68	0·04	0·03
1·63	1·92	1·00	1·20	0·23	0·20	0·38	0·26	2·03	1·96	0·04	0·05
1·42	1·69	0·60	0·96	0·19	0·21	0·42	0·28	2·05	2·05	0·07	0·08
1·90	1·97	0·90	1·00	0·22	0·21	0·45	0·30	2·09	2·26	0·07	0·07
3·33	2·86	1·40	1·72	0·22	0·22	0·41	0·35	2·86	2·73	0·08	0·07
3·13	2·79	1·40	1·69	0·20	0·22	0·56	0·37	2·92	2·89	0·09	0·07
Mature leaves primed just before turning yellow†											
10·15	10·17	1·41	1·92	0·18	0·17	0·35	0·32	4·52	4·87	0·93	0·86
8·90	9·63	1·81	2·68	0·20	0·21	0·48	0·47	4·18	4·55	0·84	0·72
7·47	9·17	1·56	3·00	0·19	0·17	0·42	0·32	4·26	4·79	0·81	0·67
6·78	8·31	1·31	2·25	0·16	0·17	0·39	0·29	4·64	4·82	0·71	0·67
Growing foliage											
1·80	1·89	0·52	1·17	0·07	0·05	0·56	0·57	2·80	1·92	0·09	0·06
1·09	1·09	1·38	0·82	0·03	0·03	0·38	0·30	0·67	0·73	0·30	0·26

† These leaves were not included in the samples for chemical analysis. ‡ Years

of the potassium content. This is borne out by the calcium and potassium contents of the leaves and stalks of mature cigar tobacco plant (13 weeks after transplanting).

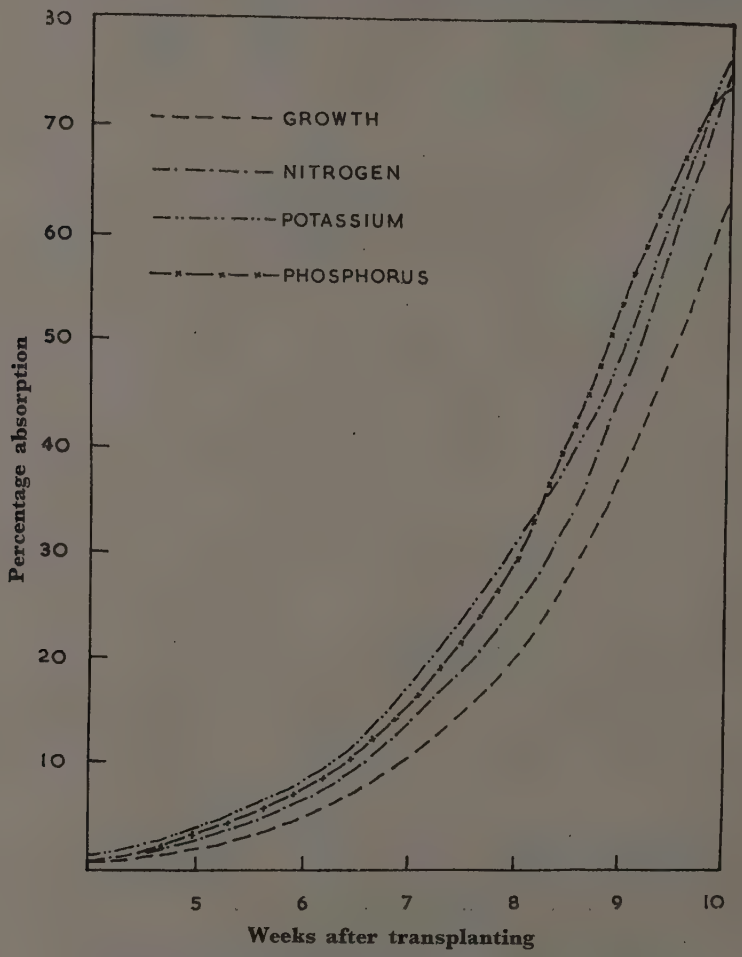

FIG. 1. RATE OF GROWTH AND RATE OF ABSORPTION OF NUTRIENTS BY CIGAR TOBACCO AT WEEKLY INTERVALS

The magnesium content of the leaves increased with age with a slight tendency to fall at maturity, while that of the stalks increased progressively. The sodium content of the leaves and stalks was the same and it did not vary with the advancing plant age; the growing foliage was, however, very poor in sodium content.

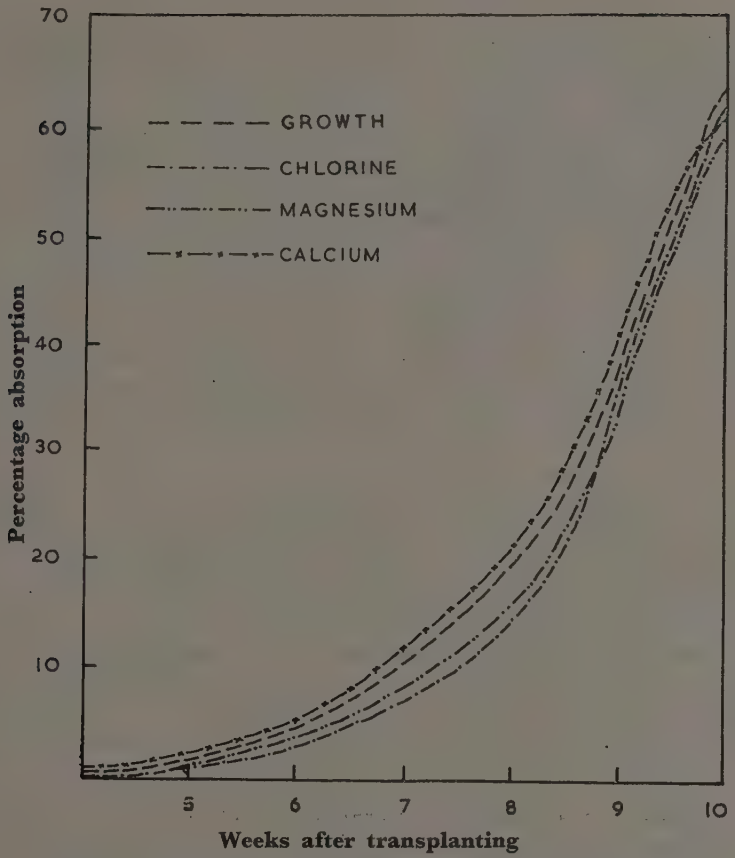

FIG. 2. RATE OF GROWTH AND RATE OF ABSORPTION OF NUTRIENTS BY CIGAR TOBACCO AT WEEKLY INTERVALS

The sulphur content of the leaves and stalks increased slightly with the advancing plant age. The sulphur content of the stalks was low during the early stages of growth but later on increased rapidly and was practically the same as that of the leaves.

The chlorine content of the leaves and stalks increased considerably with the advancing plant age, the concentration of chlorine being greater in the leaves than that in the stalks. The leaves, which were mature and primed before they turned yellow, contained more chlorine than the other green leaves or growing foliage. This suggests that the chlorine already accumulated in the leaf is not transferred to the upper leaves.

Garner [1951] has concluded that "mature tobacco seeds contain no nicotine but it promptly appears following germination and thereafter is present in all parts of the plant including the seed in its early stages of ripening". The data in Table I

indicate that four weeks after transplanting, the leaves contained 0·34 per cent nicotine which gradually increased to 0·75 per cent ten weeks after transplanting. After topping, there was a phenomenal rise in the nicotine content of the leaf. Within one week after topping, it doubled itself to 1·50 per cent; thereafter it did not increase much. The stalks were practically devoid of nicotine, which increased gradually from 0·02 per cent (at four weeks after transplanting) to 0·08 per cent (at harvesting time). The growing foliage (tops and suckers) contained considerably less nicotine than the mature leaves sampled on the same dates (leaf Nos. 8, 9 and 10, and 11 and 12). The nicotine content of the leaves which were mature and primed before they turned yellow was higher than that of the other green leaves of the corresponding sampling dates. This confirms the findings of other workers that the mature leaves have higher nicotine content than the leaves which are still growing. However, it will be noted that leaf Nos. 11 and 12 had lower nicotine content than the leaf samples of the same sampling date (29–1–1953). This may be due to the fact that these samplings were done after topping when the growing leaves were accumulating actively large quantities of nicotine.

Quantities of Nutrients Removed by Cigar Tobacco

The data for the total quantities of nutrients removed per acre by cigar tobacco plant at weekly intervals are given in Table II. The data show that on an average the cigar tobacco plant absorbed about 80 lb. nitrogen, 150 lb. K_2O, 20 lb. P_2O_5, 140 lb. CaO, 45 lb. MgO, 5 lb. Na_2O, 15 lb. S and 100 lb. Cl per acre. It also synthesized about 30 lb. nicotine. The cigar tobacco plant utilised large quantities of nitrogen, potassium, calcium, magnesium and chlorine while its requirements for phosphorus, sulphur and sodium were relatively low. Among the cations, calcium requirements of cigar tobacco plant were nearly equal to those of potassium while magnesium occupied the third rank; among the anions chlorine and nitrogen requirements were very high while those of sulphur and phosphorus were low and of the same order.

It was shown in Part I of this study [1957], that the growth of cigar tobacco plant occurred in four well defined phases of growth, namely, (i) 'establishment phase' (up to three weeks after transplanting), (ii) 'transitional phase' (fourth to sixth weeks after transplanting), (iii) 'active phase' (seventh to tenth weeks after transplanting), and (iv) 'maturation phase' (11th to 13th weeks after transplanting). The absorption of plant nutrients was also found to follow the same trend. The quantities of nutrients absorbed by the plant during each growth phase, are given in Table III.

It will be seen that up to the end of *transitional phase* of growth, only 6 per cent of total nitrogen was accumulated by the crop; during the *active phase* of growth, when the plant produced the maximum quantities of green and dry matter about 60 per cent of nitrogen was absorbed; during the *maturation phase* the demand for nitrogen continued to be high since it was required for the synthesis of nicotine and proteins and the plant absorbed about 30 per cent of its total nitrogen requirements. The accumulation of potassium, phosphorus, calcium, magnesium, sodium, sulphur and chlorine followed the same general pattern; during the *transitional phase* of growth the plant absorbed very small quantities of nutrients; during the *active phase* of growth

TABLE II. TOTAL QUANTITIES OF NUTRIENTS (lb./acre) ABSORBED BY CIGAR TOBACCO PLANT AT WEEKLY INTERVALS

Weeks after transplanting	N		K_2O		P_2O_5		CaO		MgO		Na_2O		S		Cl		Nicotine	
	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54
4	0·6	0·6	1·3	1·3	0·1	0·2	0·8	0·8	0·1	0·1	0·03	0·03	0·1	0·4	0.3	0·3	0·04	0·04
5	2·6	2·7	6·8	5·8	0·6	0·7	3·4	3·6	0·6	0·6	0·13	0·12	0·2	0·2	1.6	1·5	0·26	0·28
6	5·0	5·2	13·1	10·8	1·0	1·5	6·7	6·7	1·2	1·6	0·24	0·24	0·4	0·3	2.8	3·1	0·59	0·64
7	12·5	12·7	31·0	27·9	2·5	3·5	17·6	19·2	3·4	4·1	0·59	0·58	1·5	1·0	10.2	8·8	1·65	1·46
8	19·8	20·6	37·5	37·2	4·0	5·8	30·7	31·0	6·1	6·9	0·98	1·04	2·4	1·6	16.9	14·1	2·56	2·46
9	37·7	39·1	74·8	72·1	7·4	10·5	57·8	55·0	13·2	16·5	1·98	1·98	4·6	4.4	35·3	36·1	4·97	5·18
10	48·6	61·6	114·6	110·7	8·9	14·2	68·4	87·2	19·3	27·3	3·03	3·21	7·6	6.7	60·7	60·5	10·13	10·14
11	53·0	68·0	120·3	120·8	11·3	15·3	86·3	100·7	21·9	30·4	4·08	3·76	8·2	7.6	73·3	66·7	20·67	19·16
12	60·3	69·7	123·0	124·5	12·0	17·7	111·4	122·4	28·3	36·8	4·48	4·22	11·3	9.5	83·3	83·8	24·10	20·92
13	76·2	82·0	150·6	145·6	14·4	19·2	136·2	142·9	32·6	45·2	4·90	4·73	13·9	10.7	94·1	97·3	29·58	25·97

TABLE III. QUANTITIES OF NUTRIENTS ABSORBED BY CIGAR TOBACCO PLANT DURING EACH OF ITS GROWTH PHASES (expressed as percentage of the ultimate quantities absorbed by the plant)

Growth phase	Period in weeks after transplanting	N		K_2O		P_2O_5		CaO		MgO		Na_2O		S		Cl		Nicotine	
		52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54
Transitional phase	4th, 5th & 6th	6·56	6·29	8·70	7·43	6·95	7·65	4·92	4·70	3·68	3·52	4·90	5·07	2·88	3·13	2·97	3·23	1·99	2·46
Active phase	7th, 8th, 9th & 10th	57·22	67·52	67·39	68·61	54·86	50·02	45·30	56·35	55·52	56·96	56·94	63·21	51·80	58·84	61·53	58·96	32·25	36·58
Maturation phase	11th, 12th & 13th	36·22	26·19	23·91	23·96	38·19	43·33	49·78	38·95	40·80	39·52	38·16	31·72	45·33	39·03	35·50	37·81	65·76	60·96

the plant took up 50 to 60 per cent of various plant nutrients; and during the *maturation phase* of growth 25 to 40 per cent of various plant nutrients were absorbed. However, the general pattern of the synthesis of nicotine was quite different from that of the absorption of various plant nutrients. During the *transitional phase* only 2 per cent of total nicotine was synthesised; about 33 per cent of the total nicotine was synthesised during the *active phase*, when the plant absorbed the maximum quantities of nutrients; the maximum quantity of nicotine (65 per cent) was synthesised during the *maturation phase*. The quantities of nutrients removed by leaves and stalks separately during each growth phase are given in Table IV.

It will be seen that up to the end of *active phase* of growth the leaves were responsible for most of the nitrogen accumulated by the plant but during the *maturation phase* accumulation of nitrogen by the leaves was considerably reduced and the stalks accumulated larger quantities than the leaves. This was true for potassium, magnesium and phosphorus also. However, in the case of calcium, sodium, sulphur and chlorine the leaves accumulated considerably larger quantities than the stalks throughout the growth period. The stalks accumulated about 15 per cent, 30 per cent, 25 per cent and 20 per cent of the total calcium, magnesium, sulphur and chlorine requirements respectively of the tobacco plant and this was accomplished mostly during the maturation phase. It was noted earlier that Ca, Mg, S and Cl contents of the stalks increased with age. This would indicate that even though the leaves had nearly completed their growth, the plant continued to absorb these nutrients which were accumulated in the stalk. The leaves accumulated practically all the nicotine, the stalks accumulating only 3 per cent of the total nicotine synthesised by the plant.

The ratio, plant nutrients accumulated in the leaves/plant nutrients accumulated in the stalk (Table V), was high during the early stages of growth and progressively decreased with the advancing plant age. This indicates that during the early stages of plant growth, larger quantities of plant nutrients accumulated in the leaves than in the stalk but with advance in age this trend was reversed.

Rate of Nutrition and Rate of Growth

Grizzard *et al.* [1942] showed that the rate of nitrogen, phosphorus and potassium absorption was greater than the rate of growth of flue-cured tobacco during early stages of growth. Hawkins [1946] reported similar trend for phosphorus nutrition in the case of potatoes. Fig. 1 shows that in the case of cigar tobacco plant also the rate of absorption of nitrogen, potassium and phosphorus was greater than the rate of growth during the early stages of growth. However, Fig. 2 shows that this was not true for calcium, magnesium, sodium, sulphur and chlorine, whose rate of absorption was more or less the same as the rate of growth. The enzyme systems of the plant are built out of proteins and nucleoproteins and, thus, contain large proportions of nitrogen and phosphate. They also require certain metals and other elements, specially potassium, which acts as a catalyst for their proper functioning. This may be the reason for the disparity between the rate of absorption and the rate of growth. Moreover, rapid growth can take place only when there is an adequate quantity of enzymes present, and hence, after the plants have absorbed adequate quantities of minerals necessary for their functioning. The high concentrations of the mineral ions in the early stages

TABLE IV. QUANTITIES OF NUTRIENTS (lb./acre) REMOVED BY WHOLE PLANT, LEAVES AND STALKS DURING EACH GROWTH PHASE

Growth phase	N		K_2O		P_2O_5		CaO		MgO		Na_2O		S		Cl		Nicotine	
	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54
Transitional phase (4th, 5th and 6th weeks after transplanting)																		
Whole plant	4·4	4·6	11·8	9·5	0·9	1·3	5·9	5·9	1·1	1·5	0·21	0·21	0·3	0·3	2·5	2·8	0·55	0·60
Leaves	4·2	4·3	11·3	9·0	0·8	1·2	5·7	5·7	1·0	1·4	0·19	0·19	0·27	0·28	2·4	2·6	0·55	0·60
Stalks	0·2	0·3	0·5	0·5	0·1	0·1	0·2	0·2	0·1	0·1	0·02	0·02	0·03	0·02	0·1	0·2	..	..
Active phase (7th, 8th, 9th & 10th weeks after transplanting)																		
Whole plant	43·6	56·4	101·5	99·9	7·9	12·7	61·7	80·5	18·1	25·6	2·79	2·97	7·2	6·4	57·9	57·4	9·54	9·50
Leaves	38·3	49·0	82·0	79·5	6·5	10·8	57·2	75·1	16·2	22·5	2·18	2·29	5·8	5·5	51·2	50·8	9·31	9·24
Stalks	5·3	7·4	19.5	20·4	1·4	1·9	4·5	5·4	1·9	3·1	0·61	0·68	1·4	0·9	6·7	6·6	0·23	0·26
Maturation phase (11th, 12th & 13th weeks after transplanting)																		
Whole plant	27·6	20·4	36·0	44·9	5·5	5·0	67·8	55·7	13·3	17·9	1·87	1·52	6·3	4·0	33·4	36·8	19·45	15·83
Leaves	12·1	8·5	11·5	10·6	3·4	1·6	49·1	40·1	4·7	8·3	0·99	0·56	3·5	2·1	18·2	21·8	18·77	15·30
Stalks	15·5	11·9	24·5	24·3	2·1	3·4	18·7	15·6	8·6	9·6	0·88	0·96	2·8	1·9	15·2	15·0	0·68	0·53

TABLE V. RATIO, NUTRIENTS REMOVED BY LEAVES/NUTRIENTS REMOVED BY STALKS AT WEEKLY INTERVALS

Weeks after transplanting	N		K_2O		P_2O_5		CaO		MgO		Na_2O		S		Cl	
	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54	52–53	53–54
4	20·0	20·0	9·0	15·0	12·0	11·9	36·0	40·5	9·0	13·0	10·0	10·0	24·0	12·8	14·0	15·5
5	25·0	26·0	19·0	16·3	21·7	18·2	33·0	49·7	19·0	19·3	12·0	11·0	19·0	17·0	15·0	20·3
6	24·0	25·0	9·0	20·0	20·8	17·0	32·5	32·5	11·0	21·7	11·0	11·0	12·3	16·0	27·0	14·7
7	16·6	17·1	11·5	16·5	13·1	12·3	34·2	37·4	16·0	19·5	7·4	7.3	14.0	11.3	19.4	16.5
8	13·1	12·7	9·0	10·7	7·0	7·5	33·1	24·8	11·2	10·5	5·5	7·0	7·0	7·2	32·8	11·8
9	8·2	7·7	4·7	5·5	4·2	4·6	17·7	8·3	6·0	6·5	3·6	4·4	5·6	7·7	28·4	9·4
10	4·2	3·9	3·9	5·8	3·3	3·1	9·9	11·0	6·7	5·4	3·8	3·6	3·0	3·8	15·0	6·1
11	2·9	3·3	3·7	3·6	2·6	2·5	7·3	8·3	3·7	4·3	3·0	2·8	2·2	3·0	6·9	4·5
12	2·1	2·4	2·8	2·9	1·9	1·8	3·8	5·3	2·1	2·1	2·3	2·1	2·1	2·5	5·9	3·5
13	2·05	2·4	2·7	2·5	2·0	1·8	4·4	5·3	1·9	2·3	2·2	1·8	2·0	2·3	3·7	3·1

upto the sixth week is explained by this. These findings are also in agreement with those of Richardson and Trumble [1928].

Nutritional Balance in Tobacco

It has been shown in plant chemistry that chemical reactions take place in equivalent proportions [Bear and Prince 1945, Shear *et al.* 1942, and Van Itallie, 1938]. Bear and Prince [1945], Bear [1950], and Stewart and Bear [1952] have observed that for the individuals of any given species grown under uniform environmental conditions and harvested at a uniform stage of growth of plant, the total sum of the cations ($Ca^{++} + Mg^{++} + K^{+} + Na^{+}$) and the total sum of the anions ($NO_3^{-} + PO_4^{=} + SO_4^{=} + Cl^{-} + Si^{=}$) tend to be constant both individually and also in the ratio between them; it follows from this that these ions can mutually substitute one another to a certain extent without interfering with the growth of the plant. In the present study the nutritional balance in the cigar tobacco plant at various stages of growth has been investigated. The total sum of cations, anions and ratios between them at weekly intervals for the leaves, stalks and entire plants were calculated and are given in Table VI.

The concentration of ions is expressed in milliequivalents per 100 gm. dry matter. The data indicate that the sums of cations and anions of the leaves and the whole plant tended to decrease with the advancing age, the fall being particularly sharp at the tenth week after transplanting; in the case of stalk the sums of cations and anions tended to increase gradually with growth. The ratio, sum of cations/sum of anions, however, remained constant for the leaves, stalks and whole plants. The data, therefore, clearly bring out the point that though the quantities of cations and anions absorbed varied with the age of the plant, a balanced relationship existed between them throughout the growth. This finding is of particular importance for cigar tobacco where it is essential that for good burning quality of the leaf the potassium content should be high and the chlorine content should be as low as possible. The above finding clearly suggests the possibility of controlling, within certain limits, the potassium and chlorine contents of the cigar tobacco leaf by proper fertiliser schedules.

Fertilisation of Cigar Tobacco

The slow growth and absorption of nutrients during establishment and transitional phases of growth as compared with very rapid and active growth, and absorption of nutrients during the active and maturation phases of growth, suggests that only small quantities of plant nutrients may be available to the plant during early stages of growth, whereas large quantities of plant nutrients should be available to the plant during the later stages of growth. Considering the nitrogen requirements of the crop, it would appear that the fertiliser practices should be so adjusted as to supply a moderate dose of fertiliser (20-30 lb. N) at the time of transplanting and a considerably large dose (70-80 lb. N) at the end of transitional phase and at the time of 'mummatty digging.'*

As already shown, cigar tobacco is a luxuriant consumer of potassium. The importance of potassium in promoting the burning quality of the leaf is well established [Schloesing, 1860; and Anderson *et al.*, 1932]. It is generally believed that Indian

* *Mummatty digging* is a deep hoeing and earthing up with a spade given six weeks after transplanting.

TABLE VI. RATIO, SUMS OF CATIONS/SUMS OF ANIONS FOR LEAVES, STALKS AND WHOLE PLANT AT WEEKLY INTERVALS

(Expressed as milliequivalents per 100 gm. of dry matter)

Weeks after trans-planting	Leaves						Stalks						Whole Plant					
	1952–53			1953–54			1952–53			1953–54			1952–53			1953–54		
	Cations	Anions	Ratio	Cations	Anions	Ratio	Cations	Anions	Ratio	Cations	Anions	Ratio	Cations	Anions	Ratio	Cations	Anions	Ratio
4	439·11	415·03	1·06	427·13	421·84	1·01	223·97	233·48	0·96	237·91	232·89	1.02	418·46	397·45	1·05	408·84	408·14	1·00
5	467·25	423·47	1·10	445·28	427·57	1·04	225·65	226·97	0·99	231·86	251·04	0·92	449·81	410·46	1·10	429·61	412·70	1·04
6	481·47	418·07	1·15	458·34	445·24	1·03	227·07	245·36	0·93	240·41	257·33	0·93	461·74	405·67	1·14	441·68	430·16	1·03
7	459·65	428·97	1·07	468.12	424·06	1·10	238·72	252·48	0·95	251·64	253·90	0·99	429·26	412·83	1·04	438·59	407·85	1·08
8	418·61	422·74	0·99	423·66	423·39	1·00	252·92	262·67	0·96	262·66	265·95	0·99	398·86	404·82	0·99	407·27	403·61	1·01
9	414·39	427·31	0·97	411·52	452·22	0·91	283·16	270·18	1·05	282·45	279·06	1·01	390·70	401·08	0·97	388·10	419·05	0·93
10	342·74	375·27	0·91	408·70	454·99	0·90	221·54	212·55	1·04	249·50	264·43	0·94	313·72	351·13	0·89	368·21	401·33	0·92
11	345·09	366·66	0·94	413·01	446·07	0·93	250·69	252·82	0·99	258·50	277·96	0·93	326·47	348·74	0·94	370·78	394·40	0·94
12	324·26	334·24	0·97	363·04	401·60	0·90	327·12	311·83	1·05	326·70	311.61	1·05	325·47	331·62	0·98	351·14	371·30	0·95
13	345·99	344·18	1·01	371·82	383·02	0·97	315·73	336·77	0·94	318·05	318·86	1·00	336·92	335·74	1·00	354·18	366·89	0·97

soils have good potassium reserves [Ramamoorty *et al.*, 1952]; this is also evident from the lack of response of cigar tobacco to the application of potassic fertilisers. However, with continuous cultivation of cigar tobacco it may not be possible for the soil to supply such large quantities of potassium indefinitely. It is, therefore, essential that the question of potassic fertilisation of cigar tobacco should be considered from time to time. The potassium requirements of cigar tobacco suggest that fractional application of potassic fertiliser in the proportion of 1:3 at the time of transplanting and *mummatty digging* (six weeks after transplanting and at the end of *transitional* phase of growth) respectively may be beneficial. However, since potassium is not subject to severe leaching [Kohnke *et al.*, 1940], one application at the time of transplanting may also serve the purpose.

As the phosphorus requirements of cigar tobacco are low, it would appear that the normal manuring with farmyard manure which is universally done at 10 to 15 tons per acre would meet the phosphorus requirements of the cigar tobacco.

Although chlorine is not regarded as an essential element, it has a decided effect on the growth of tobacco plant and the quality of cured leaf. The tobacco plant will absorb and build up large quantities of chlorine in the leaf tissues if this element is available to it in the soil and fertiliser and as much as 10 per cent chlorine can be built up in the leaf. It is generally believed by the American workers that chlorine content of 1 per cent or more in the leaf is definitely harmful to the leaf burn. It will be noted that the chlorine content of the cigar tobacco leaf samples reported in this paper is considerably high and an acre of the crop has removed about 100 lb. of chlorine. The source of this large quantity of chlorine was the well water which contained 310 p.p.m. chlorine.* Cigar tobacco crop receives about 16 irrigations. Even at the low rate of 1 acre-inch irrigation each time, the total quantity of chlorine added by irrigation water will be 1,125 lb. per acre. The contribution of chlorine from farmyard manure used for the fertilisation of the crop was about 14 lb. These data, therefore, suggest that steps should be taken to reduce the chlorine content of the leaf by irrigating tobacco from those wells where the chlorine content of the water is particularly low. Fertilisers containing chlorine e.g., ammonium chloride and potassium chloride cannot, therefore, be recommended.

SUMMARY

The concentration, the quantities absorbed and the rate of absorption of nitrogen, potassium, phosphorus, calcium, magnesium, sodium, sulphur and chlorine and the concentration and the synthesis of nicotine by the leaves, stalks and the whole cigar tobacco plant at weekly intervals as grown in South India have been studied. The nutritional balance in the cigar tobacco plant and its fertiliser requirements have been discussed.

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VERSENE-FLUORIDE REAGENT FOR ESTIMATION OF AVAILABLE SOIL PHOSPHORUS

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Great interest is taken in India in soil testing for evaluation of phosphorus fertility status of soils and prediction of the need for phosphatic fertilizers. A rapid, suitable and useful soil test shall have a number of essential characteristics [Bray, 1948]. In a recent study, a comparison was made of the more important soil-test methods by using a wide variety of Indian soils and the crops of wheat and paddy [Datta and Kamath, 1957]. It was found that of all the methods tried, the 0·5 M $NaHCO_3$ method [Olsen *et al.*, 1954] was the best. It gave highly significant correlations with yield responses in both wheat and paddy. However, evolution of carbon dioxide on acidification of the extract for estimation of phosphorus in this method makes it not quite suitable for adoption in rapid test procedures. Extraction of colouring matter from soils for which phosphate-free Darco G60 has to be added is also an extra step. Search for a method which may be free from the above defect and may at the same time be good for determination of soil phosphorus led us in investigation of this proposed method.

Some of the important phosphorus containing materials in soil are apatites, calcium phosphates, iron and aluminium phosphates including phosphorus bound or sorbed on the surface of hydrated iron, and aluminium phosphates and organic phosphates [Russell and Russell, 1950]. It can be viewed that phosphorus available to plants is chiefly derived from various forms of calcium phosphates, iron and aluminium phosphates and exchangeable or replaceable phosphate.

Sodium salts of ethylene diamine tetra acetic acid (versenes) are stable in solution and are powerful complexing agents. They form soluble nonionic chelates with iron, calcium or other divalent or polyvalent ions. Log K (equilibrium constant) values of versene chelate compounds are 25·1 for Fe^{+++}, 14·2 for Fe^{++}, and 10·59 for Ca^{++} [Bersworth chemical company, 1952]. The strength of the versene complex is so great that versene will dissolve or bring into solution phosphorus from insoluble compounds, say for example calcium phosphates through the reaction, $Ca_3(PO_4)_2 + 3\,Na_4\,Ver \rightarrow 3\,Na_2\,(CaVer) + 2Na_3PO_4$.

Solubility of some samples of calcium phosphates, apatite, ferric and aluminium phosphates in versene or versene-flouride solutions was determined. The results are given in Table I.

It will be seen that both calcium and iron or aluminium phosphates are soluble, though the former is more soluble than the latter. Solubility of apatite is very little. The high solubility of aluminium phosphate in versene fluoride solutions is due to the well-known action of fluoride on aluminium salts.

TABLE I. SOLUBILITY OF PHOSPHORUS COMPOUNDS IN VERSENE AND VERSENE-AMMONIUM FLUORIDE SOLUTIONS AT 25°C.

Compound	Microgram phosphorus dissolved on half hour shaking in 50 cc. of 0·1 per cent versene solution		Microgram phosphorus dissolved on half hour shaking in 50 cc. of 0·1 per cent versene + 0·03 N NH_4 F solution	
	*p*H 5·1	*p*H 8·2	*p*H 5·1	*p*H 8·2
Dicalcium phosphate	1,825	1,825	1,825	1,825
Tricalcium phosphate	1,825	1,825	1,825	1,825
Apatite (fluor)	90	32	78	29
Ferric phosphate	225	126	390	140
Aluminium phosphate	125	462	4,500	3,450

Versene will also prevent 'refixation' of phosphorus by calcium and iron ions compounds due to its strong chelating actions with these. Kurtz *et al.* [1946] found the replacing ability of anions for sorbed phosphate to be in the following increasing order: chloride, sulphate, thiocyanate, acetate, borate, bicarbonate, citrate, oxalate and fluoride. This high efficiency of fluoride has been used by Bray [1948] in his method and has been utilized with advantage here also.

MATERIAL AND METHODS

The soils used and methods followed for evaluation were the same as those described in an earlier paper [Datta and Kamath, 1957] and the details are given there.

EXPERIMENTAL METHODS

Phosphorus in versene-fluoride extracts of soils: The estimation of phosphorus by Dickman and Bray [1940] method in versene-fluoride solution was found to be simple, the standard curve conforming to Beer's Law over the colour range studied. To see whether there was any interference in colour development or its stability, in the estimation of phosphorus in soil extracts with versene fluoride solutions of strengths as proposed here, some recovery studies of added phosphorus in such extracts of widely different soils were made. The results are given in Table II. It is apparent that estimation of phosphorus in versene fluoride extracts of soils is straight-forward and accurate.

To study the effect of fluoride ion, 11 different soils under greenhouse wheat (1955-56) and 20 soils under greenhouse paddy (1955) were selected. The extracting solutions were 0·1 per cent versene with and without 0·03 N NH_4F, and pure 0·03 N NH_4F; *p*H was 5·1, soil: solution ratio 2·5gm: 50 cc. and one half hour shaking was used. The correlation coefficients for the extractable soil phosphorus and percentage yield response are given in Table III.

It will be found that fluoride helped to increase the numerical value of the correlation coefficient, thereby showing an improved relationship with yield response than that with versene alone. This confirms the recent observations of Viro [1955].

TABLE II. RECOVERY OF ADDED PHOSPHORUS FROM VERSENE AMMONIUM FLUORIDE EXTRACTS OF SOILS

Soil	Soil Extract aliquot used (in cc.)	Phosphorus added (in micrograms)	Phosphorus found (in micrograms)	Per cent recovery
	5	..	2.30	..
Karjat (Bombay)	5	5	7.30	100.0
	5	10	12.25	99.5
	5	..	4.65	..
Dhanpur (Rajasthan)	5	5	9.70	101.0
	5	10	14.45	98.0
	5	..	5.59	..
Sumerpur (Rajasthan)	5	5	10.49	98.0
	5	10	15.39	98.0
	5	..	7.01	..
Nachiarthotam (Madras)	5	5	12.10	101.8
	5	10	16.81	98.0

TABLE III. EFFECT OF FLUORIDE IN VERSENE SOLUTION ON THE CORRELATION BETWEEN EXTRACTABLE SOIL PHOSPHORUS AND PER CENT YIELD RESPONSE

	Correlation coefficient	
	Wheat, 1955–56 (No. of soils=11)	Paddy, 1955 (No. of soils=20)
0·1 per cent versene, *p*H 5·1	–0·631*	–0·404
0·1 per cent versene + 0·03N NH_4F, *p*H 5.1	–0·840†	–0·790†
0·03 N NH_4F	–0·720*	–0·350

* Significant at 5 per cent level.
† Significant at 1 per cent level.

Eleven different soils from a greenhouse experiment on wheat, in 1955-56, to study phosphorus response with different doses of phosphate were used to study the variables, concentration of versene, *p*H, soil: solution ratio and time of shaking. The results on extractable soil phosphorus and their correlation coefficients with percentage yield response are given in Table IV.

There is gradual increase in the amount of soluble phosphorus with concentration of versene and so also the numerical value of the linear correlation coefficient. However, it was observed that at 0·2 per cent a few soils started giving coloured

TABLE IV. EFFECT OF CONCENTRATION OF VERSENE; *p*H, SOIL SOLUTION RATIO AND PERIOD OF SHAKING ON EXTRACTABLE SOIL PHOSPHORUS (lb. P_2O_5/acre) BY VERSENE—AMMONIUM FLUORIDE SOLUTION

Wheat 1955–56 (11 soils)	Concentration of versene in per cent (*p*H 5·1, 2·5 gm. soil /50 cc., ½ hour shaking)				*p*H (0.1% versene, 2.5 g soil/50 cc., ½ hour shaking)				Soil solution ratio (0.1 % versene, *p*H 5.1, ½ hour shaking) 2·5 g soil in			Period of shaking (0.1 % versene, *p*H 5.1, 2.5g soil/50 cc.)		
	0·05	0·075	0·1	0·2	4·0	5·1	7·0	8·0	25cc.	50 cc.	100 cc.	¼ hr.	½ hr.	1 hr.
Tahsil (Saurashtra)	0	0	0	8	0	0	0	0	0	0	0	0	0	0
Sunderwada (M.P.)	0	0	0	5	0	0	0	0	0	0	9	0	0	0
Zamani (M.P.)	22	26	29	34	32	29	28	20	17	29	41	26	29	32
Obaidullaganj (M.P.)	1	2	2	10	4	2	2	0	0	2	15	3	2	3
Bagwai (M.P.)	2	4	5	10	5	5	5	0	2	5	16	6	5	7
Titwala (Bombay)	2	7	10	32	18	10	6	2	3	10	45	7	10	10
IARI Farm (Middle Block, Delhi)	71	95	102	128	114	102	90	66	57	102	141	95	102	113
IARI Farm (Main Block, Delhi)	1	10	19	31	21	19	12	7	4	19	32	19	19	21
IARI Farm (Top Block, Delhi)	0	0	12	31	0	12	2	0	2	12	23	12	12	10
Waksal (Bombay)	26	49	63	103	85	63	56	60	16	63	139	62	63	64
Karnal (Punjab)	19	33	36	48	30	36	46	59	16	36	59	31	36	38
Correlation coefficient with % yield response	–0.770†	–0.816†	–0.840†	–0.874†	–0.852†	–0.840†	–0.844†	–0.858†	–0.748†	–0.840†	–0.881†	–0.822†	–0.840†	–0.820†

† Significant at 1 per cent level.

extracts. The effect of *p*H was not so marked and the values of the correlation coefficients were about the same. This certainly is a welcome feature with the method in that, in most methods when extracting solution of a definite *p*H is added to the soil, the *p*H changes differently depending on the nature of the soil; this exerts a variable influence on ultimate soluble phosphorus that is obtained. The effect of variation in soil: solution ratio is very pronounced, a ratio of 2·5 gm. soil in 100 cc. is definitely superior. Soluble phosphorus or its correlation with per cent yield response does not seem to be greatly influenced by time of shaking. Considering all factors the following method is proposed.

The Proposed Method

Prepare a 0·1 per cent solution of disodium salt of ethylene diamine tetra acetic acid in water and add 1·11 gm. NH_4F per litre to make it 0·03 N in respect of fluoride. The *p*H of this solution is about 5·1 and needs no adjustment. The solution is perfectly clear and stable. Shake 2·5 gm. air-dry soil passing through 2 mm. in 100 cc. of the above solution for half hour in a mechanical shaker. Filter immediately through washed No. 42 Whatman or similar filter paper and estimate phosphorus directly in a 5 or 10 cc. aliquot by Dickman and Bray [1940] method.

RESULTS AND DISCUSSION

Greenhouse experiments were conducted on six groups of soils to obtain a measure of yield response to phosphorus. Two of these experiments were on wheat, one on oats and three on paddy. The 78 soils in the six groups came from as many locations in the country and represented most of the major soils. In four experiments, phosphorus was applied as radioactive superphosphate permitting a measure of 'A' value [Fried and Dean, 1952] to be obtained. Twenty-seven soil samples from as many field experiments on wheat, in 1955, on cultivators' fields were also used.

To evaluate the method, analysis of the relationship between the phosphorus soluble in versene fluoride solution expressed in pounds P_2O_5 per acre (2×10^6 pounds of soil) and per cent yield response, and 'A' value was done through calculation of correlation coefficients (r), the prediction value (also called coefficient of determination $r^2 \times 100$), by preparation of scatter diagram, curve fitting, and frequency distribution tables. Correlation coefficients between soil test values and per cent yield response are given in Table V. For comparison the value of the correlation coefficient for the $NaHCO_3$ method has also been included in this table.

It will be seen that the values of the correlation coefficients are significant and are quite high in all the greenhouse experiments on wheat and paddy, and that they are just as good as those for the $NaHCO_3$ method—in fact the numerical values with the former method is slightly though not significantly higher than those of the latter. The same findings are also true in the case of the average values of 'r'. As usual, the value of 'r' for the field experiment though significant is much lower than that for the greenhouse experiment. The prediction value for versene fluoride method comes out to 70·7 and 62·1 for wheat and paddy respectively while the corresponding figures for the $NaHC0_3$ method are 56·5 and 57·5.

Against 'A' values the correlation coefficients with this method are also highly significant, the average values being +0·881 for wheat and +0·801 for paddy.

TABLE V. CORRELATION COEFFICIENT OF SOIL TEST VALUES FOR PHOSPHORUS BY THE VERSENE-FLUORIDE METHOD AND PER CENT YIELD RESPONSE OR 'A' VALUE IN EXPERIMENTS ON WHEAT AND PADDY

Experiment		No. of soils	Per cent yield response				'A' value	
			Versene flouride	Average	Olsen	Average	Versene fluoride	Average
Greenhouse								
Wheat	1954–55	12	–0·813†		–0·767†			
Oats	1955	6	–0·795	–0.841†	–0·708	–0.752†	+0.741	+0.881†
Wheat	1955–56	11	–0·881†		–0·754†		+0.912†	
Paddy	1954	11	–0·641*		–0·618*			
Paddy	1955	18	–0·806†	–0.788†	–0·671†	–0.758†	+0.693†	+0.801†
Paddy	1955	20	–0·824†		–0·855†		+0.867†	
Field								
Wheat	1955	27	–0·438*		–0·413†			

* Significant at 5 per cent level.
† Significant at 1 per cent level.

The soil-test values have been plotted against per cent yield response to obtain the scatter diagrams shown in figures 1 and 2. These scatter diagrams make it apparent that the relationship probably is not a linear one but curvilinear. Transformation of the soil test values to a log scale showed an increase in the correlation values in most of the experiments. This is particularly so in the paddy series, the average value of 'r' increasing from 0·788 to 0·881. Curvilinear regression equations for wheat and paddy calculated to give a better description of the variations are given in the following

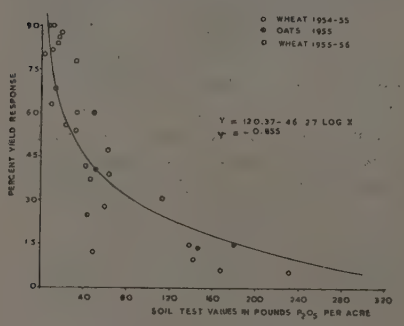

FIG. 1. RELATIONSHIP BETWEEN SOIL TEST VALUES BY VERSENE-FLUORIDE METHOD AND PER CENT YIELD RESPONSE IN GREENHOUSE EXPERIMENTS ON WHEAT

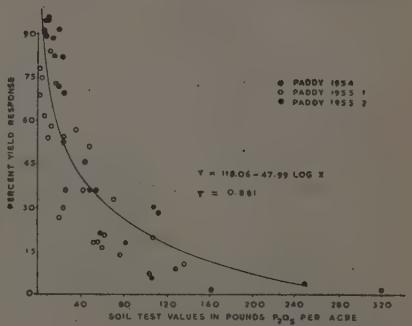

FIG. 2. RELATIONSHIP BETWEEN SOIL TEST VALUES BY VERSENE-FLUORIDE METHOD AND PER CENT YIELD RESPONSE IN GREENHOUSE EXPERIMENTS ON PADDY

figures. The constants for the regression equation representing the two crops are in good agreement, suggesting just as in the case of the 0·5M $NaHCO_3$ method (Datta and Kamath, 1957] that the soil-test values for both the crops will represent similar ranges in soil fertility. This also suggests that the method is equally applicable to soils cropped under arable or submerged conditions.

Scatter diagrams for soil-test values for both wheat and paddy and 'A' values show a linear relationship between these variables as indicated in Figs. 3. and 4.

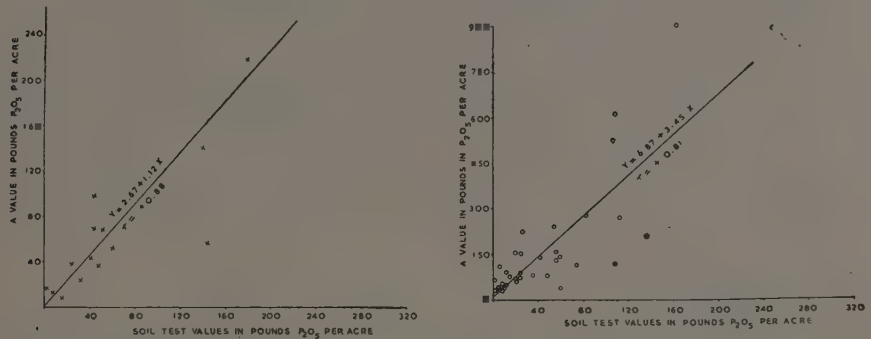

FIG. 3. RELATIONSHIP BETWEEN SOIL TEST VALUES BY VERSENE-FLUORIDE METHOD AND 'A' VALUES IN GREENHOUSE EXPERIMENTS ON WHEAT

FIG. 4. RELATIONSHIP BETWEEN SOIL TEST VALUES BY VERSENE-FLUORIDE METHOD AND 'A' VALUES IN GREENHOUSE EXPERIMENTS ON PADDY

They also confirm what was observed earlier when the relationship between soil test values and per cent yield response was considered, namely that the same ranges in the classification of soil-test values by this method for both wheat and paddy are suitable.

Assuming that the available phosphorus as determined by the 0·5 M $NaHCO_3$ method is a good measure of the phosphorus fertility status of the soils the accuracy with which this value may be predicted from the versene fluoride soil-test value can be determined from the regression line relating these two variables. This relationship for all the soil samples under study irrespective of crop grown is shown in Fig. 5. The correlation coefficient is +0·91 and the regression is y=7·87+0·444.X

One of the principal objectives of a soil test is to be able to group soils into different fertility classes for suggesting fertilizer recommendation, similar fertilizer recommendation being made for all soils falling in the same group. The frequency distribution of soils according to per cent yield response and soil-test value is shown in Table VI.

The soils have been separated into three groups, those showing less than 25 per cent. yield increase, those from 25-50 per cent and those over 50 per cent. On the basis of relationship shown in Figs. 1 and 2 the limits for soil-test values have been chosen as <30, 30–80 and >80 lb. P_2O_5/acre. The performance of the method for classification desired is obviously as good as can be expected. Based on results reported here, the level of versene flouride soluble phosphorus is as follows: <30 lb. P_2O_5/acre a response, 30-80 lb., a probable response and >80 lb. a response unlikely. These values are applicable to both wheat and paddy crops.

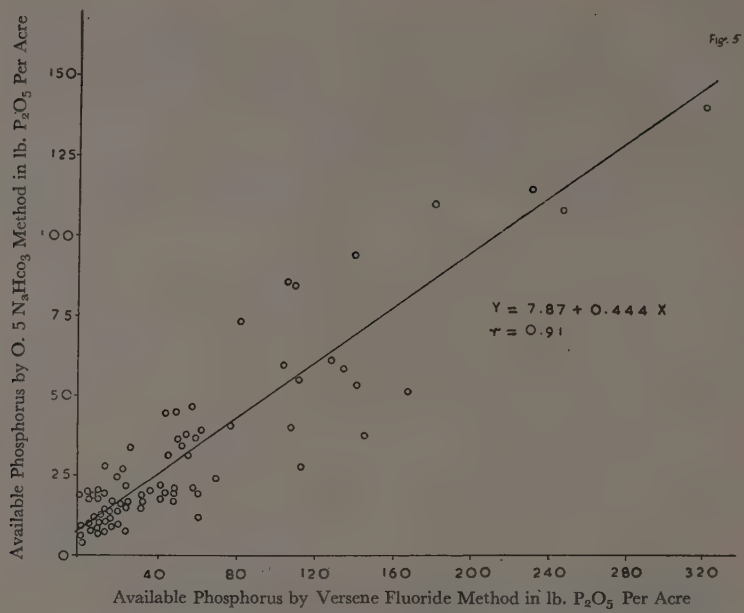

FIG. 5. RELATIONSHIP BETWEEN SOIL-TEST VALUES BY VERSENE-FLUORIDE METHOD AND 0·5M $NaHCO_3$ METHODS IN GREENHOUSE EXPERIMENTS ON WHEAT AND PADDY

TABLE VI. THE FREQUENCY DISTRIBUTION OF SOIL-TEST VALUES GROUPED ACCORDING TO PER CENT YIELD RESPONSE

Pounds P_2O_5 per acre	Per cent yield response on wheat (no. of samples in each group)			Per cent yield response on paddy (no. of samples in each group)		
	25%	25-50%	50%	25%	25-50%	50%
30	0	0	12	0	3	22
30–80	1	7	2	6	6	1
80	6	1	0	9	2	0

SUMMARY

A new method for extraction of available phosphorus in soils for wheat and paddy crops is described. The method uses 0·1 per cent versene solution made 0·03 N in respect of flouride, a soil: solution ratio of 1:40 and one half hour shaking. The method is adoptable to rapid routine soil testing procedures.

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COMPARATIVE STUDY OF AVAILABLE PHOSPHORUS IN INDIAN SOILS AS ESTIMATED BY DIFFERENT METHODS

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Several methods exist for the estimation of available phosphate in soils like Dyer's [1894], Das's [1930], Olsen's [1952], Bray's [1929], Truog's [1930], Wrangell's [1926], Puri and Asghar's [1936] methods, etc. Out of these, only such of the methods will be useful which give correlation between the available phosphate and crop responses. Before these correlations are worked out, it is considered desirable to have information on the actual amount of phosphates estimated by different important methods in different soil types of the country and the present work has this object in view.

For the purpose of this study three methods Das's, Truog's and Olsen's have been selected to compare their values on different soils of the country, with those of the classical method (Dyer's 1 per cent citric acid).

MATERIAL AND METHODS

Twentyfive soils from different parts of India have been selected for this study. Six soils namely Bijapur, Surat, Sholapur, Khare, Waresoni and Kheri represent black soil areas; eleven soils Berhampur, Travancore, Pattambi, Bidar, Lalwadi, Sunderkhera, Mansong, Coimbatore, Rangpur, Talipramba and Mangalore represent red and laterite soil areas; and soils Nadiad, Ajmer, Karnal, Ferozepur, Aligarh, Izatnagar, Pusa and Delhi represent the alluvial area.

The available phosphorus was estimated from the surface soils of the above places by (a) 1 per cent citric acid method (Dyer's), (b) Das's 1 per cent potassium carbonate method, (c) Truog's method (N/500 H_2SO_4, *p*H adjusted to 3·0), and (d) Olsen's method (0·5 molar sodium bicarbonate, *p*H adjusted to 8·5). In the first two methods the standard Pemberton's method was followed for the estimation of phosphate and in the latter two methods the colorimetric procedure was adopted. In Olsen's method the decolourization of the extract for the colorimetric estimation was made by oxidation with potassium permanganate and removal of the excess of permanganate with sodium sulphite instead of the activated charcoal as recommended by the author.

In order to assess the general nature of the soils, they were examined for *p*H, total soluble salts, organic nitrogen, HCl soluble phosphate, potash and lime, and exchangeable potassium, sodium and calcium. The HCl extract was made by the official method of the I.S.S.S. Exchangeable calcium was estimated by leaching with sodium chloride while potassium and sodium was estimated by N ammonium acetate extraction. Total nitrogen was estimated by digestion with concentrated sulphuric acid and refers to total organic nitrogen.

DISCUSSION

The soils have been classified broadly on the basis of the soil type and the data pertaining to black soils are presented in Table I and Ia. The *p*H of the soils is practically between 7 to 8 except for Bijapur which has a *p*H of 8·5. The calcium in the soils varied considerably from 0·23 to 6·93 although potassium content was fairly within narrow limits (0·22 per cent to 0·48 per cent). The soils contain moderate amounts of organic nitrogen and hence carbon, and are fairly rich in the exchangeable calcium. The soils (except one) are not generally rich in the total phosphate content (HCl soluble). There does not appear to be any relationship between the total phosphate and the available phosphate as estimated by different methods. In general, the citric acid method has extracted more of available phosphate and is closely followed by Olsen's method and Das's method. There does not appear to be any similarity in the amounts of phosphate extracted by different methods in this soil type. In view of the fact that there were only six soils in this group, no statistical calculation was worked out.

TABLE I. BLACK SOILS

Place	Description of soil (Inches)	*p*H	T.S.S.	Available P in lb./acre			
				Dyer's	Olsen's	Das's	Truog's
Bijapur	Deep black soil 0–9	8·5	0·1	55	52·3	13·1	13·1
Surat	Surface soil 0–9	7·5	0·05	60·2	7·9	13·1	15·8
Sholapur	Deep soil 0–9	7.2	0·09	13·1	15·8	15·8	15·8
Khare	Unirrigated 0·9	7·4	0·1	48·8	40·1	21·8	13·1
Waresoni	Cultivated soil 0–9	7·3	0·05	36·6	7·9	34·9	9·6
Kheri	Cultivated soil 0·9	6·9	0·03	34·0	7·9	61·0	15·8

TABLE Ia. BLACK SOILS

HCl Extract			Total	Exchangeables in m.e. per 100 gm. of soils		
CaO (%)	K_2O (%)	P_2O_5 (in lb./acre)	Org. N (%)	Ca	Na	K
6·93	0·40	1,134	0·04	39·0	3·0	0·33
1·28	0·22	696	0·03	37·7	3·55	0·44
1·14	0·36	64	0·04	59·0	2·8	0·4
2·36	0·45	1,316	0·07	44·0	1·8	0·3
0·23	0·31	620	0·06	13·5	1·6	0·23
0·6	0·48	1,162	0·04	32·2	2·0	0·27

The data with regards to red and lateritic soils are given in Tables II and IIa. The *p*H of the soils mostly vary from 5 to 7·5 except for the Coimbatore soil which has

a *p*H of 8·2. The soils are low in calcium (both total and exchangeable) and the contents of the total phosphate are fairly good in most of the soils.

TABLE II. RED AND LATERITE SOILS

Place	Description of soil (Inches)	*p*H	T.S.S.	Available P in lb./acre			
				Dyers'	Olsen's	Das's	Truog's
Berhampur	Unmanured cultivated 0–9	7·2	0·14	116·8	15·8	88·9	9·6
Travancore	Virgin forest soil 0–9	7·0	0·2	76·7	26·5	119·4	19·2
Pattambi	Surface soil 0–9	6·1	0·12	20·9	4·2	52·2	26·5
Bidar	Surface soil 0–9	6·5	0·01	124·4	35·6	36·2	41·8
Lalwadi	Surface soil 0–9	7·6	0·5	128·8	64	68	67·7
Sunderkhera	Surface soil 0–9	6·6	0·01	395·8	15·8	33·1	25·2
Mansong	Normal crop grass 0–9	4·8	0·2	202·7	64·5	189·5	3·2
Coimbatore	Cultivated soil 0–9	8·2	0·1	95	15·8	7·9	9·6
Rangpur	Tobacco soil 0–9	6·1	0·1	491·4	80·2	347·1	64·0
Talipramba	Surface soil 0–9	5·8	0·1	193·5	7·9	8·0	38·4
Mangalore	Paddy breeding area 0–9	5·8	0·03	117·6	7·9	41·8	13·1

TABLE IIa. RED AND LATERITE SOILS

HCl extract			Total	Exchangeables in m. e. per 100 gm. of soils		
CaO (%)	K_2O (%)	P_2O_5 (in lb./acre.)	Org. N (%)	Ca	Na	K
0·16	0·14	1,162	0·06	6·8	1·9	0·29
0·13	0·32	5,208	0·18	6·1	1·7	0·36
0·07	0·13	2,362	0·13	2·5	1·6	0·26
0·11	0·20	3,042	0·05	7·7	1·0	0·48
0·26	0·36	4,988	0·13	20·3	1·6	0·19
0·13	0·22	2,710	0·04	16·9	1·4	0·45
0·12	0·48	4,750	0·19	5·0	1·28	0·22
2·34	0·55	852	0·05	25·8	2·8	0·23
0·21	0·55	3,680	0·07	3·5	1·9	0·19
0·12	0·11	2,470	0·07	3·2	1·7	0·39
0·15	0·11	1,732	0·05	2·9	1·1	2·23

The available phosphate figures extracted by 1 per cent citric acid is on the average comparatively higher than those obtained with the other methods. In the soils coefficient of correlation between 1 per cent citric acid method and Das's method works out to 0·604 significant at 5 per cent level while the coefficient of correlation between Olsen's and Das's method is 0·783 significant at 1 per cent level. The Truog's method however gave positive correlation with citric acid method although it did not appear to be significant.

In Tables III and IIIa are presented the data for alluvial soils. The *p*H of these soils are mostly on the alkaline side. There is a wide variation in the lime content although the exchangeable calcium expressed m.e. for most of the soils are not high. The total phosphate is moderately good in most of the soils.

TABLE III. ALLUVIAL SOILS

Place	Description of soil (Inches)	*p*H	T.T.S.	Available P in lb./acre			
				Dyer's	Olsen's	Das's	Truog's
Nadiad	Not irrigated for 10 years 0–9	7·6	0·1	108·1	5·2	133·4	106·3
Ajmer	Banani area 0–9	7·3	0·1	133·8	7·9	20·6	9·6
Karnal	Surface soil 0–9	9·3	0·3	153·4	33·6	38·4	7·9
Ferozepur	–do–	8·1	0·3	46·8	7·9	32·7	5·4
Aligarh	Unirrigated 0–9	7·5	0·1	184·8	7·9	58·8	126
Izatnagar	Sandy soil 0–9	7·0	0·1	100·8	25·6	154·1	7·9
Pusa	Low land by the river 0–9	8·3	0·1	10·4	15·8	20·9	64·5
Delhi	Surface soil 0–9	8·1	0·1	67·2	4·2	20·3	7·9

TABLE IIIa. ALLUVIAL SOILS

HCl extract			Total Org. N (%)	Exchangeables in m. e. per 100 gm. of soils		
CaO (%)	K_2O (%)	P_2O_5 (in lb./acre.)		Ca	Na	K
1·12	0·37	790	0·05	10·9	2·1	0·23
0·34	0·23	1,154	0·04	6·4	1·2	0·59
0·46	0·57	1,760	0·05	1·9	3·5	0·31
2·7	0·81	1,162	0·04	12·7	3·7	0·36
0·38	0·51	1,798	0·05	5·8	1·6	0·26
0·21	0·54	1,712	0·06	4·4	2·4	0·31
14·6	0·27	1,736	0·04	7·9	1·4	0·25
0·81	0·27	944	0·04	10·2	1·7	0·16

The available phosphate extracted by Dyer's method was found to give positive correlation with the other methods but they were generally low or insignificant.

The values of the total phosphate were also found to give significant correlation with Dyer's (+0·437 at 5 per cent level), Das's (+0·56 at 1 per cent level) and Olsen's (+0.62 at 1 per cent level) methods. The Truog's method showed a very poor correlation with the total phosphate.

Considering all the soils together, the values obtained by Das's method were found to be best correlated with 1 per cent citric acid coefficient of correlation being 0·6 significant at 1 per cent level. There was also significant correlation at 5 per cent level between the Olsen's method and citric acid method. The correlation coefficient between the Truog's method and citric acid method was found to have no correlation at all.

The available phosphate obtained by Olsen's method has been found to give significant correlation with Das's method (+0·63 at 1 per cent level). Truog's method showed no correlation with Olsen's or Das's method.

Classifying the data on the basis of *p*H into two groups namely acidic and alkaline soils (vide Table IV and V), the coefficient of correlation between Olsen's and Das's methods was found to be highly significant (+0·88 at 1 per cent level) in acid soils, while there was no significant correlation between the rest. On the alkaline soils, there was no significant correlation between any two of the methods.

TABLE IV. ACIDIC SOILS

Place	*p*H	Available P in lb./acre			
		Dyer's	Olsen's	Das's	Truog's
Kheri	6·9	34·0	7·9	61·0	15·8
Travancore	6·0	76·7	26·5	119·4	19·2
Pattambi	6·1	20·9	4·2	53·2	26·5
Bidar	6·5	124·4	35·6	36·2	41·8
Sunderkhera	6·6	395·8	15·8	33·1	25·2
Mansong	4·8	202·7	64·5	189·5	3·2
Rangpur	6·1	491·4	80·2	347·1	64·0
Talipramba	5·8	193·5	7·9	8·0	38·4
Izatnagar	7·0	100·8	25·6	154·1	7·9
Mangalore	5·8	117·6	7·9	41·8	13·1

Classifying the soils on the basis of the total exchangeable bases (Tables VI and VII), there was significant correlation at 1 per cent level between any two methods, except between Dyer's and Truog's and Das's and Truog's methods in the soils having exchangeable bases below 10 m.e., while in soils having higher exchangeable figure, there was no significant correlation except Das's and Truog's (+0·88 at 1 per cent level).

TABLE V. ALKALINE SOILS

Place	*p*H	Available P in lb./acre			
		Dyer's	Olsen's	Day's	Truog's
Bijapur	8·5	55·0	52·3	13·1	13·1
Surat	7·5	60·2	7·9	13·1	15·8
Sholapur	7·2	13·1	15·8	15·8	15·8
Khare	7·4	48·8	40·1	21·8	13·1
Waresoni	7·3	36·6	7·9	34·9	9·6
Berhampur	7·2	116·8	15·8	88·9	9·6
Lalwadi	7·6	128·8	64·0	68·0	67·7
Coimbatore	8·2	95·0	15·8	7·9	9·6
Nadiad	7·6	108·1	5·2	133·4	106·3
Ajmer	7·3	133·8	7·9	20·6	9·6
Karnal	9·3	153·4	33·6	38·4	7·9
Ferozepur	8·1	46·8	7·9	32·7	5·4
Aligarh	7·5	184·8	7·9	58·8	126·0
Pusa	8·3	10·4	15·8	20·9	64·5
Delhi	8·1	67·2	4·2	20·3	7·9

TABLE VI. TOTAL EXCHANGEABLE BELOW TEN

Place	Total exchangeables	Available P in lb./acre			
		Dyer's	Olsen's	Das's	Truog's
Ajmer	8·2	133·8	7·9	20·6	9·6
Karnal	5·7	153·4	33·6	38·4	7·9
Berhampur	8·99	116·8	15·8	68·9	9·6
Aligarh	7·66	184·8	7·9	58·8	126·0
Izatnagar	7·11	100·8	25·6	154·1	7·9
Mansong	6·42	202·7	64·5	189·5	3·2
Rangpur	5·59	491·4	80·2	347·1	64·0
Travancore	8·16	76·7	26·5	119·4	19·2
Pusa	9·55	10·4	15·8	20·9	64·5
Pattambi	4·36	20·9	4·2	53·2	26·5
Mangalore	4·2	117·6	7·9	41·8	13·1
Talipramba	5·3	193·5	7·9	8·0	38·4
Bidar	9·2	124·4	35·6	36·2	41·8

TABLE VII. TOTAL EXCHANGEABLES ABOVE TEN

Place	Total exchangeables	Available P in lb./acre			
		Dyer's	Olsen's	Das's	Truog's
Nadiad	13·23	108·1	5·2	133·4	106·3
Bijapur	42·3	55·0	52·3	13·1	13·1
Surat	38·6	60·2	7·9	13·1	15·8
Sholapur	62·2	13·1	15·8	15·8	15·8
Khare	46·1	48·8	40·1	21·8	13·1
Ferozepur	16·8	46·8	7·9	32·7	5·4
Waresoni	15·3	36·6	7·9	34·9	9·6
Kheri	34·5	34·0	7·9	61·0	15·8
Coimbatore	28·8	95·0	15·8	7·9	9·6
Delhi	12·1	67·2	4·2	20·3	7·9
Lalwadi	22·1	128·8	64·0	68·0	67·7
Sunderkhera	18·7	395·8	15·8	33·1	25·2

The above discussion and data obtained so far indicate the correlations between different methods only, in different soil types. The final test for their suitability or otherwise depends entirely on the correlations that can be obtained between the available figures and actual crop responses. The large number of experiments which are proposed to be conducted under the coordinated Agronomic Trial Scheme of the Indian Council of Agricultural Research will enable to establish correlation in typical black, red, alluvial and lateritic soil zones.

SUMMARY

A comparison of the available phosphate values as obtained by Olsen's method, Truog's method, Das's method and Dyer's method in soils representing different parts of India gave the following results:

1. On soil type basis, there was a significant correlation in red and laterite soils between Dyer's and Das's and Olsen's and Das's method. There was no significant correlation between any two methods in alluvial soils.

2. On *p*H basis, there was significant correlation between Olsen's and Das's methods in acid soils while there was no significant correlation between any two methods in alkaline soils.

3. In soils of low base exchange capacities, there was a significant correlation between any two methods except between Truog's and Dyer's and Truog's and Das's methods, while in soils of high base exchange capacities, there was no significant correlation except between Das's and Truog's methods.

4. Considering all soils together, the values obtained by Das's method correlated well with Dyer's method and to some extent with Olsen's method. Truog's method shows no correlation with Olsen's and Das's methods.

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A METHOD FOR RADIOAUTOGRAPHIC STUDY OF MOVEMENT OF PHOSPHORUS IN SOIL COLUMNS

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Since Henderson and Jones [1941] outlined the method for using radioactive isotope in the movement studies of phosphorus in soil systems, several workers, notably Jordan *et al.* [1952] and Heslep *et al.* [1954] have used this principle in the mobilization study of phosphates in thin soil sections. Johnston [1954] described an autoradiographic procedure for measurement of longitudinal displacement of P^{32} labelled H_3PO_4 solution. This was considered to be an improvement over the Geigertube measurement of successive thin soil sections, which did not show anything as to the pattern of penetration of the nutrient. Cutting the longitudinal sections of the treated soil columns offered the greatest difficulty. Moist soil columns were pushed out into lucite tubes, longitudinally cut in half, where it was frozen before cut by a bandsaw shielded in a glove box.

During the course of a similar study here, it was observed that the moist soil column undergoes considerable degree of compaction while being pushed out of the tube, thus accounting for a probable source of error. Cutting of the frozen soil column with a bandsaw was also a problem. It was, therefore, thought desirable to find out a simpler means for cutting through the soil column in the percolation tube itself and yet not spoiling it for subsequent use.

MATERIAL AND METHODS

Leaching tubes were sections of perspex tubing of 3 inches outer diameter and $2\frac{1}{2}$ inches inner diameter. Further, each tube was cut longitudinally into two halves with clean edges. The two halves were then sealed with half inch cellophane tape running along the length. To the bottom of the tube was next fitted a metal cap having a few round holes. A six-inch deep soil column was then packed to normal field density, in these tubes. The top surface of the soil in the column was covered with perforated celluloid disc to protect it from erosion due to inflow of the leaching solutions. A metal cap with a center hole was slid on top. This sealing arrangement worked well for all types of treatments except in case where the soil column was under flooding. In the latter treatment the bottom of the percolation tube was sealed watertight against a plastic disc with durofix. Six such leaching tubes were supported on a frame (Plate 1) having arrangement for leaching under a constant head, and collection of leachates.

After the leaching was over, the columns were allowed to stand for 24 hours to bring equilibrium in the moisture content throughout the column. A plug was put on the top to reduce evaporation. The metal caps and the perforated celluloid discs were then removed. The cellophane tape was cut through with a sharp edged blade

along the suture to admit a stretched pianoforte wire, size 34 gauge, which was then passed through along the suture. This splitted the column into the clean halves (Plate II).

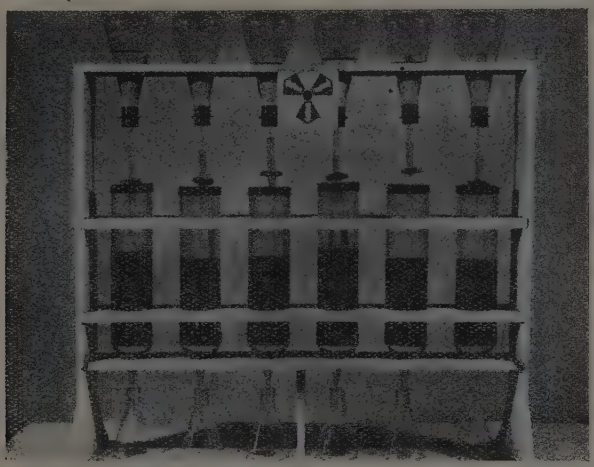


PLATE 1. LEACHING TUBES IN A FRAME

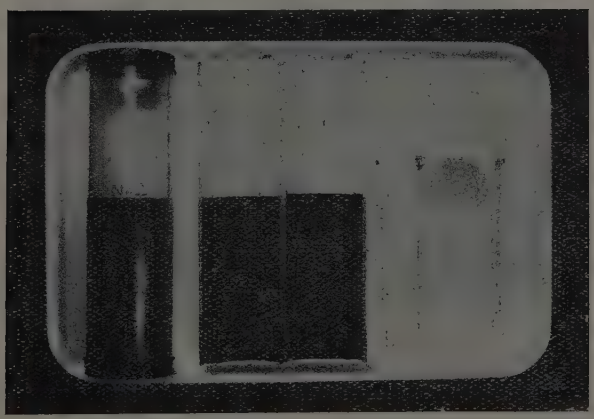


PLATE II. SPLITTING OF SOIL COLUMNS

The six half columns were inserted in the semi-circular channels of the camera as shown in Fig. 1 and Plate III. This was essentially of the type described by Yagoda [1949], for measuring emanating power of polished surfaces. Kodirex no screen X-ray film enclosed in very thin alkathene bags, to avoid contact between the X-ray film and moist soil, was used for autoradiograph. In order to cut off radiation coming

from the contaminated upper part of the perspex column a moulded aluminium sheet sliding along the collar of the sectioned half column in the camera was used. Exposure given was as per Wintering [1955]. The film after suitable exposure was processed in D-19 developer and F-5 fixer.

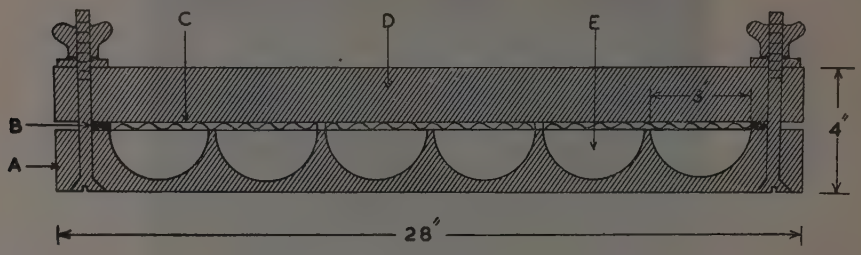


FIG. 1. CROSS-SECTION THROUGH THE CAMERA

A. Painted wood-block accommodating six perspex mounted half columns.
B. Sponge gasket between the wood-block and the clamping plate.
C. X-ray film in alkathene bag.
D. Clamping plate.
E. Groove accommodating the perspex half column.

PLATE III. CAMERA

The method described has the advantage of being simple and yet taking care of the difficulties pointed out earlier while discussing the previous methods.

It will be useful to note that soils which undergo considerable shrinkage on wetting, are not quite suitable for radioautographic study by this method, as they allow movement through channels without any diffusion through main soil column. Soils which have gravel or root debris larger than 2 mm. size, need also be sieved prior to filling into the column. Cutting of the soil column and other processes are conveniently done behind a perspex shield to prevent radiation exposure. The wire can either

be easily decontaminated or a set of them kept for different samples to avoid cross contamination.

The method is not restricted in its use on phosphorus alone, but is equally adoptable for movement and translocation studies with other nutrients having suitable isotopes.

RESULTS AND DISCUSSION

The leaching solution whose volume was calculated as equivalent to a single irrigation dose to wet up to 6 inches had the soluble phosphate Ca $(H_2PO_4)_2$ (superphosphate) at the rate of 40 lb. P_2O_5/acre and containing 16μC. P^{32} dissolved in it. To simulate normal fertilizer practice nitrogen and potassium at 40 lb. N or K_2O/acre was applied along with superphosphate. Movement was studied by allowing this solution to percolate through the soil column. The soil treatments were (i) control i.e. untreated soil, (ii) soil kept flooded for two weeks under a constant head of two inches of standing water and drained before leaching, and (iii) soil composted with bulky organic matter (20 tons F.Y.M./acre) and kept for four weeks before being leached.

Three widely different soil types whose characteristics are given in Table I, were used to make an autoradiographic study of movement of phosphorus under various proposed treatments with this method.

TABLE I. GENERAL CHARACTERISTICS OF THE SOILS USED

Soils	pH (1:2.5)	Moisture equivalent (per cent)	Free $CaCO_3$ (per cent)	Free sesquioxides % (Jeffries, 1946)	P fixing capacity[a] (per cent)
Waksal Ratnagiri–Bombay	6·3	29·4	Nil	7·5	71·0
Zamani Hoshangabad–M.P.	7·5	18·3	trace	2·8	42·0
Top Block I.A.R.I. Farm-Delhi	7·9	14·2	trace	1·3	43·1

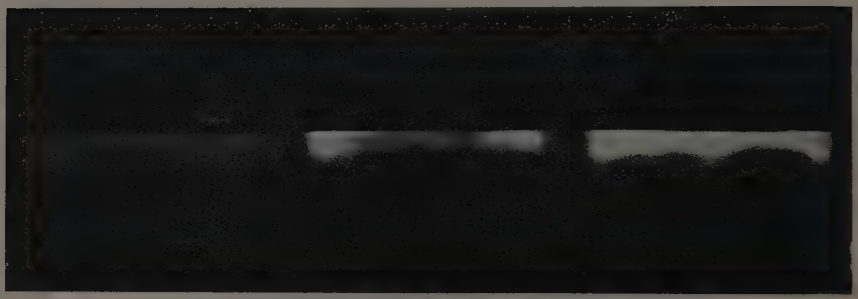
[a] Modified Floyd (1943) method: Extracting solution was 0·5M $NaHCO_3$ solution of pH 8·5.

The autoradiographs of the movement of phosphorus under these treatments for the three soils are shown in Plates 4, 5 and 6. It would be seen that the movement of phosphorus under treatment No. 1 was minimum for the heavy soil [Waksal, laterite] having high free sesquioxide content and maximum for light soil (I.A.R.I., Delhi, alluvium) of low content of free sesquioxides. Effects of flooding was to move phosphorus deeper in Soil No. 1 and 3 but very little in Soil No. 2. Flooding a soil for a long time induces marked reducing conditions as well as increased hydrolysis of soil phosphates. In laterites or soils containing predominantly iron phosphate systems reduction of ferric to ferrous state will reduce fixation and consequently lead to greater movement of applied phosphates. Incidently these processes will increase available soil phosphates also. In calcium phosphate systems, as is in this black cotton soil from Zamani, these processes are not operative and this probably explains the observation. Effect of organic matter in mobilizing phosphorus has been marked in all soil types and may have been either because of improvement in soil structure or reduction in fixing capacity through production of organic acids or large complex molecules from decomposition of F.Y.M. which chelated calcium and iron. Observation of Sokolov and Koritskaya [1948] suggest that decrease in phosphorus fixation and

1 2 3

PLATE 4

SOIL : WAKSAL-RATNAGIRI, BOMBAY
1. CONTROL 2. FLOODING 3. ORGANIC MATTER



1 2 3

PLATE 5

SOIL : ZAMANI, HOSHANGABAD, M. P.
1. CONTROL 2. FLOODING 3. ORGANIC MATTER

1 2 3

PLATE 6

SOIL : TOP BLOCK, I. A. R. I. FARM, NEW DELHI
1. CONTROL 2. FLOODING 3. ORGANIC MATTER

increase in the size of aggregates may be accompanied by increased movement. But it is more probable that organic acids Swanson *et al.*, [1949] or complex organic molecules Bradley and Sieling, [1953] produced from F.Y.M. chelated calcium or iron and led to increased movement of phosphorus. It is of interest to note also that in case of laterite soil (Soil No. 1) flooding treatment, which created reducing conditions, was as effective as organic matter in increasing phosphate movement.

SUMMARY

In the method developed split plastic tubes with sutures sealed with cellophane tape are used. These were found to be better leaching columns for subsequent sectioning for radioautographic study. After the experiment the cellotape was cut along the seams by a sharp edged blade. A stretched steel pianoforte wire passed through the soil column then gives smooth uncontaminated soil sections. This eliminates the necessity of sliding soil columns out of leaching tubes and freezing for subsequent sectioning by bandsaw. The method along with accessory leaching apparatus and camera described here is adaptable for use on six or more soils in one run. A moulded aluminium sheet sliding along the collar of the sectioned half in the camera was used to cut off beta radiation coming from contaminated upper part of the perspex column.

Movement of tagged fertilizer phosphorus in a number of different soils under different treatments has been studied with this method. The depth of movement was found to be minimum for heavy soil having high free sesquioxide content and maximum for light soil of low content of free sesquioxide. The effect of bulky organic matter was to significantly increase the movement in all the soils, but the greatest effect was in black cotton and the alluvial soils. The laterite soil flooding treatment, which created reducing conditions, was as effective as organic matter in increasing phosphate movement.

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STUDY OF QUALITY OF UNDERGROUND AND IRRIGATION WATER IN CHAMBAL COMMANDED AREA OF RAJASTHAN

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Received: March 19, 1958

The area to be commanded by Chambal Project lies in south-east of Rajasthan between 24°N to 25·8°N latitude and 75·5° to 76·5° E longitude in Districts of Bundi and Kotah. This investigation includes the areas in Kotah District, east of Chambal river. The climate of the area is tropical with average rainfall of 31 inches most of which is received during monsoon. The Chambal, the Kallisindh and the Parbati rivers, seasonal nalas and gullies, constitute the main drainage of the commanded area.

The commanded area is about 6,00,000 acres out of which only about one per cent is under irrigation by wells. With the introduction of irrigation, a study on the quality of underground waters and their depth is very necessary to predict any possible danger of waterlogging or development of salinity and alkalinity. Amongst the many workers, mention may be made of Raychaudhary [1947], Basu [1950], and Thorne and Peterson [1954] who have pointed out hazards of high underground water-table and poor quality of irrigation and underground waters. Shaw [1952] has established that six feet is the critical depth for underground water-table, otherwise it is likely to create a problem.

Many workers at different times have recommended various standards to interpret the quality of water. A review of literature reveals that the most effective standards are the total soluble salts and the kind of salt which predominates. Wilcox [1948] classifies water into various qualities of suitability depending upon electrical conductivity and sodium percentage. Taylor, *et al.* [1944] evolved a salt index for characterising all irrigation waters. Asghar and Dhawan [1947] made comparison with the above salt index and its relationship to the total salts content, Ca/Na ratio and *p*H value. Quantity of irrigation waters in Uttar Pradesh have been reported by Agarwal and Mehrotra [1952-53]. Agarwal *et al.* [1956], Richards [1947], Eaton [1950] and Wilcox [1951] have also proposed various methods of classification of waters. Latest type of classification of quality of waters has been reported in a publication on the manual of U. S. Salinity Laboratory [1954] wherein waters have been characterised into four grades of alkalinity in terms of sodium adsorption ratio, making up 16 classes in all. This is a definite improvement over previous classification, as it represents salinity, alkalinity or salinity-alkalinity hazards in waters. Thorne and Peterson [1954] have modified this classification, keeping the fundamental idea the same, but dividing the salinity classes into five divisions.

No information was available about the quality of underground and irrigation waters of the area under study. In the Chambal area, irrigation will be done by canals but interpretation of quality of waters on the basis of their soluble salt contents, sodium adsorption ratio and residual alkalinity will serve as a very useful guide for knowing

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the quality of underground waters and its effect on soil properties. In the present investigation modified classification of Thorne and Peterson has been used for categorisation of water.

MATERIAL AND METHODS

The Chambal commanded area, on the basis of soil survey investigation, has been classified into following nine groups. The general characters of each group are given in Table I.

TABLE I. GENERAL CHARACTERS OF THE SOIL GROUPS OF THE CHAMBAL COMMANDED AREA

Soil group	Description	Texture	Land rating class
1	Grey soils without *kankar* layer	Loam and clay loam	One
2	–do–	Clay	One
3	Grey soils with *kankar* layer	Clay loam and clay	One
4	Brown soils without *kankar* layer	Clay loam and clay	One
5	–do–	Loam	One
6	Brown soils with *kankar* layer	Loam and clay loam	One
7	Grey and brown soils without *kankar* layer	Loam and clay loam	Two
8	Grey soils without *kankar* layer and *Kankar* layer below four feet	Loam and clay loam	Three
9	Grey soils without *kankar* layer and *Kankar* layer above four feet	Loam and clay loam	Four

Land rating classes have been fixed according to the suitability of land for irrigation and the nature and extent of probable problems that may come up after irrigation. Rating class-one land has no problem and is ideal for irrigation. This covers a large part of the area and for a closer representation, this group has been further sub-divided into different groups based on colour of surface soil, presence and depth of *kankar* layer. Rating class-two land has slight to moderate problems, while classes three and four have severe problems of salinity, alkalinity, waterlogging and drainage.

Water samples from wells were collected at the time of profile examination from a number of places distributed in each of the nine groups. The time of collection of samples was kept uniform as far as possible for each group. Side by side, water-table was observed at the time of sampling and during the monsoon period. Number of samples, depth of wells, water-table at sampling time and during monsoon period of all nine groups is given in Table II. Six water samples from Chambal River were also analysed to determine the quality of irrigation water.

Water samples from wells were analysed for cations and anions by usual laboratory methods as described in U.S.D.A. Hand Book No. 60. Sodium has been determined by deducting bivalent cations from total anions. Sodium per cent was calculated

as $Na \times 100/Total\ cations$, possible sodium per cent as $Na \times 100/(Total\ cations) - (CO_3 + HCO_3)$, residual alkalinity as $(CO_3 + HCO_3) - (Ca + Mg)$ and sodium adsorption ratio as $Na \sqrt{Ca + Mg}\ 2$. For representation of sodium adsorption ratio, electrical conductivity was converted into total soluble salts by multiplying with the conversion factor 0·64.

EXPERIMENTAL METHODS

The results of analysis of water samples are shown in Table III and diagramatically represented by Fig. I. The values have been averaged for each soil group showing the number of samples collected. The deviations in soluble salts, sodium percentage and other ratios namely residual alkalinity, sodium adsorption ratio, possible sodium percentage, sodium per cent present are shown in Table IV.

Except in soil groups 3, 8 and 9 where total salts are high ranging from 0·15 to 0·23 per cent, the results indicate that the composition of water on the whole is medium-high salt content. The *p*H value ranges from 7·6 to 7·85 which indicates that waters are on slightly alkaline side. Generally, divalent cations exceed the monovalent cations. But in soil groups (3, 6, 8 and 9) with *kankar* layer and rating class three and four monovalent cations predominate. Carbonates are low and bicarbonates are predominant where sulphates and chlorides are low. In group 3 (heavy grey soils with *kankar*), 8 and 9 (soils with problems of drainage, salinity, etc.) high amount of sulphates are present. Chlorides are present in toxic concentration in group 3 (heavy grey soils with *kankar*), otherwise they are below the injurious limit.

River water is of medium salt content where bivalent cations predominate. Among anions, bicarbonates predominate and carbonates, sulphates and chlorides are low.

The water-table of all of this group reached during monsoon is on the average below the critical limit of ten feet. In rating class-four only the level is six feet.

TABLE II. RESULTS OF THE PROFILE EXAMINATION OF WATER SAMPLES

Soil group	No. of samples	Total depth of wells (in feet)	Water-table at the sampling time from the surface (in feet)	Monsoon water table from the surface (in feet)
1	50	46	32	20
2	20	49	30	21
3	4	36	26	17
4	21	46	34	23
5	16	43	28	20
6	8	48	33	23
7	12	38	27	20
8	10	52	33	19
9	2	35	16	6

TABLE III. AVERAGE COMPOSITION AND TOTAL IONIC CONCENTRATION OF EACH SOIL GROUP

Soil group	No. of samples	pH	Total salts p.p.m.	Cations e.p.m.			Anions e.p.m.				Total concentration e.p.m.
				Calcium	Magnesium	Sodium	Carbonate	Bicarbonate	Chloride	Sulphate	
1	55	7·83	1,303	7·53	4·46	9·14	0·70	9·06	2·97	8·40	21·13
2	20	7·78	1,076	4·17	5·05	9·10	0·69	10·28	2·65	4·70	18·32
3	7	7·75	2,302	8·85	5·60	22·08	0·45	8·14	10·47	17·47	36·53
4	21	7·85	1,079	6·54	3·55	7·93	0·52	12·06	1·90	3·54	18·02
5	19	7·81	1,125	6·57	3·69	8·35	0·25	10·58	2·77	5·01	18·61
6	10	7·78	1,371	4·89	4·41	13·83	1·04	13·61	4·22	4·26	23·13
7	22	7·60	1,045	6·05	4·23	7·32	0·92	10·53	2·54	3·61	17·60
8	11	7·80	1,573	6·06	5·12	13·56	Nil	7·71	3·88	13·15	24·74
9	4	7·75	1,825	6·69	6·04	16·86	0·50	8·95	5·79	14·35	29·59
				Chambal river water							
10	6	7·66	240	2·87	0·87	0·21	0·27	2·67	0·67	0·34	3·95

TABLE IV. DEVIATIONS IN TOTAL SALTS AND Na PER CENT AND DERIVED RATIOS S.A.R. RESIDUAL ALKALINITY AND SODIUM PER CENT PRESENT AND POSSIBLE

Total salts p.p.m.		Per cent sodium		Observed $\frac{Na \times 100}{Total}$	Possible $\frac{Na \times 100}{Total\ (CO_3+HCO_3)}$	Residual alkalinity (CO_3+HCO_3) (–) (Ca+Mg)	S. A. R. value $\frac{Na}{Ca+Mg/2}$	Water quality
Max.	Min.	Max.	Min.					
5,600	268	75·0	0·00	43·25	80·0	Nil	3·73	C_3–S_1
2,194	495	91·5	6·40	49·66	100·0	1·76	4·24	„ „
5,812	782	80·6	18·10	60·44	79·0	Nil	8·21	C_4–S_3
1,724	362	85·2	2·00	44·00	100·0	2·49	3·53	C_3–S_1
2,101	640	77·0	0·00	45·00	100·0	0·57	3·69	„ „
4,112	290	81·0	0·41	59·79	100·0	5·35	6·41	C_3–S_2
1,826	432	84·3	0·81	41·61	100·0	1·17	3·17	C_3–S_1
2,728	604	80·1	6·00	54·82	79·0	Nil	5·73	C_4–S_2
4,001	553	76·7	50·70	56·98	84·0	Nil	6·68	„ „
304	186	19·0	0·00	5·30	33·7	Nil	0·15	C_2–S_1

According to Magistad and Christianson [1944] water with total soluble salts less than 700·0 p.p.m. and less than 60 per cent of sodium are excellent to good water, while

with 700 to 2,000 p.p.m. of total salts and 60 to 75 per cent sodium are good to injurious and over 2,000·0 p.p.m. of total salts and more than 75 per cent sodium are injurious to unsatisfactory. From these standards, waters of the area are good to injurious but sodium per cent is generally within permissible limits. In soil group 3 (grey soils with *kankar* layer) soluble salts are 2,302 p.p.m. and sodium per cent is 55 per cent which falls in close limit of unsatisfactory water.

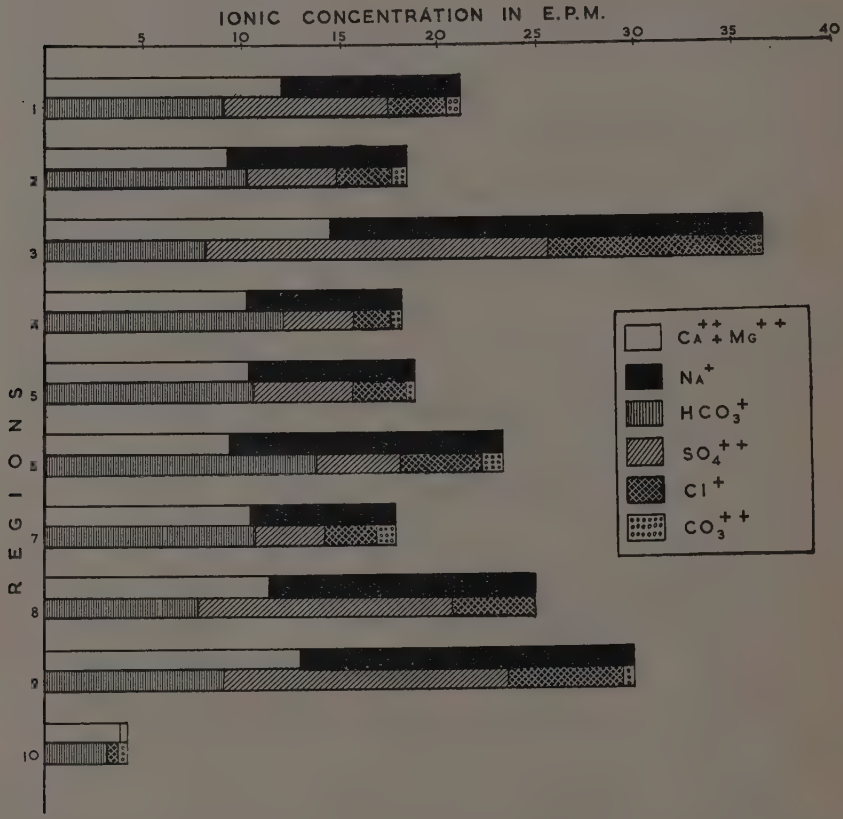

FIG. 1. SHOWING DISTRIBUTION OF SALTS IN EACH REGION OF CHAMBAL COMMANDED AREA OF RAJASTHAN

In terms of Eatons classification, waters with more than 2·5 m.eq./litre of residual sodium carbonate are not suitable for irrigation, 1·25 to 2·5 m. eq./litre are marginal and less than 1·25 m.eq./litre are probably safe. Based on this, waters of the group (2, 4 and 6) are of poor quality where possible sodium per cent is 100 and residual

alkalinity ranges from 1·76 e.p.m. to 5·35 e.p.m. Soils in these groups are well drained and the water-table is low which may help in decreasing the effect of residual alkalinity.

According to the categorisation system wherein the use of sodium adsorption ratio is made as suggested by U.S. salinity laboratory [1954] and modified by Thorne and Peterson [1954], as many as 119 samples out of 170 fall in medium-high salt group, 35 in high salt group, 10 in very high salt group and only 6 in medium salt group. The sodium adsorption ratio of individual water samples are plotted in Fig. 2. In general water falls in the classes C_3-S_1, C_3-S_2 and C_4-S_2. Waters in grey soils with *kankar* layer fall in the class of high salinity and high alkalinity (C_4-S_3) and that of rating classes three and four in high salinity and medium alkalinity (C_4-S_2). River water falls in the class medium salinity and low alkalinity (C_2-S_1).

Out of these three systems, the classification in terms of sodium adsorption ratio is more appropriate as it predicts the inherent hazards of salinity and alkalinity. The quality of water based on this classification has been found to be correlated with the soil types. In soil groups (1, 2, 4 and 5) where water-table is low and soils are deep and well-drained waters are in C_3-S_1 class (i.e. moderately saline and low alkalinity). As such, the chances of development of salinity are fairly remote.

In soil groups (3 and 6) with *kankar* layer, because of preponderance of precipitated calcium carbonate, the underground waters are rich in sodium and fall in class C_4-S_3 (Group 3) and C_3-S_5 (Group 6). The waters are comparatively more saline and alkaline. As such if water-table of these areas rise, the accumulation of salts will be speeded up and serious problems of salinity and alkalinity are likely to develop. Hence irrigation should be given very judiciously, with proper drainage facilities and suitable cropping. In rating classes three and four (i.e. group 8 and 9) the waters are in C_4-S_2 class (i.e. highly saline and moderately alkaline). These areas have already problems of poor drainage and waterlogging and Group 9 has also high underground water-table. The areas in these two groups are liable to severe danger of alkalinity and salinity. To meet the problem, same measures as that of groups 3 and 6 should be adopted except that these should be intensively followed. River water is of good quality and there does not seem to be any possible danger for the development of salinity or alkalinity, as a result of its application on land.

It can be inferred from the above discussion that the river water is of good quality and needs no supplemental practices. The quality of underground waters indicates if water-table is not allowed to rise beyond the critical level of ten feet it may not prove harmful. In groups 3, 6, 8 and 9 special care is needed to check the rise of water-table in order to prevent the development of salinity and alkalinity.

SUMMARY

Well waters from different places in Chambal-commanded area of Kotah district were examined in detail for their quality along with river water. The river water has been found to be good for irrigation. The quality of waters vary with the depth and drainage of the soils. Most of the waters fall in medium-high saline class. Classification of waters has been done on basis of sodium adsorption ratio and its effect on soil groups were studied.

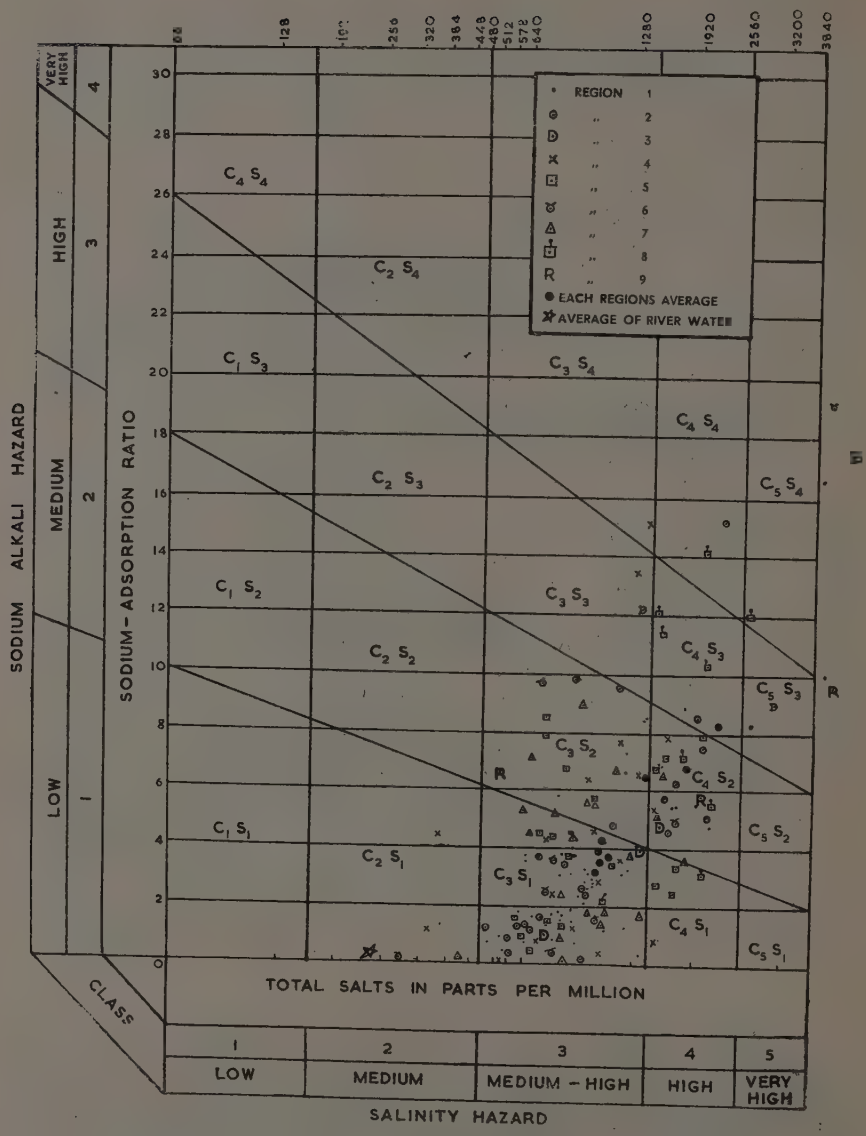

FIG. 2. QUALITY OF IRRIGATION WATER IN CHAMBAL COMMANDED AREA OF RAJASTHAN

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THE GENETICS OF *CORCHORUS* (JUTE)

VIII. INHERITANCE OF NON-RUGATE CAPSULE CHARACTER IN *C. CAPSULARIS* LINN.

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Capsules of *C. capsularis* show a wide range of variation in size. They may be small, medium or big in size depending on their longer and shorter axes which vary from 1·31 to 1·63 cm. and 0·80 to 1·20 cm. respectively. The shape of the capsule also differs and it may be globate or obovate with pod indices (length and breadth ratios) ranging between 0·85 and 1·64. Ghose [1942] studied the inheritance of capsule shape in *C. capsularis* and established a monogenic inheritance for this character. He has shown that globular capsule character is dominant over obovate (oval) character and the factor-pair controlling this character has been designated as G-g, Globular oval. He also showed that the capsule shape gene G, was linked with the chromogen gene C, with 8 per cent crossing over. The capsules of different sizes and shapes described above, are all rugate, i.e. outer surface of their pericarp is marked by blunt outgrowths that give it a wrinkled and rough appearance. The authors came across a type which bore capsules having a non-rugate (smooth) surface. The investigations reported here deal with the mode of inheritance of the non-rugate capsule character.

MATERIAL AND METHODS

The non-rugate capsule type was isolated from a *capsularis* material received from China in the year 1951. It is a non-branching type and the capsules, besides being non-rugate, are obovate in shape. In all other characters it resembles the Indian types of *C. capsularis*.

The Indian type with rugate capsule employed in this study is a strain originally isolated from a material called *Kajla comilla*. Globate capsule and branching habit are the other two features of this type in contrast to those of the non-rugate exotic type.

EXPERIMENTAL RESULTS

Relationship of the Rugate with the Non-rugate Capsule Type

Kajla comilla (rugate capsules) was crossed with Chinese type (non-rugate capsules). The F_1 bore rugate capsules like *Kajla comilla*, the Indian type. In the F_2 generation, the progenies segregated into rugate and non-rugate phenotypes as shown in the next page:

F_2 Family	Capsules		Total
	Rugate	Non-rugate	
4,477	120	41	161
4,478	106	32	138
4,479	88	24	112
4,481	192	58	250
Total	506	155	661
Expected (3:1)	495·75	165·25	661·00

X_2=0·85 P=0·50–0·30

Back crosses of the F_1 with the rugate parent gave progenies which were all rugate, while back crosses with the non-rugate parent segregated into rugate and non-rugate phenotypes as follows:

Back-cross family	Capsules		Total
	Rugate	Non-rugate	
4,490	1	1	2
4,491	6	4	10
4,492	7	6	13
4,493	..	1	1
Total	14	12	26
Expected (1 : 1)	13	13	26

X^2=0·1538 P=0·90–0·95

From the data presented above, it is evident that the dominance of rugate over the non-rugate capsule character is determined by a single factor pair which may be designated as Ru-ru.

The F_2 progenies were segregated for the globate and obovate capsule character, as well as for the branching and non-branching habit. Advantage was taken of this to investigate the linkage relationship, if any, of the factor pair, Ru-ru, with the factor pairs, G-g and Br-br, controlling capsule shape and branching habit characters.

Capsule Surface and its Shape

The classification of the F_2 progenies on the basis of dihybrid segregation of capsule surface and its shape is given below:

F_2 Family	Rugate capsule		Non-rugate capsule		Total
	Globate	Obovate	Globate	Obovate	
4,477	98	22	33	8	161
4,478	80	26	22	10	138
4,479	75	13	18	6	112
4,481	144	48	38	20	250
Total	397	109	111	44	661
Expected (9 : 3 : 3 : 1)	371·81	123·94	123·94	41·31	661·00

X_2=5·03 P=0·20–0·10

It may be seen from the above data that the phenotypes fall in the expected 9:3:3:1 ratio and there is no evidence of linkage.

Capsule Surface and Branching Habit

Patel, Ghose and Sanyal [1945] have shown that the branching habit in *C. capsularis* is dominant over the non-branching habit and the factor pair controlling this character has been designated as Br-br (Branched-non-branched). The F_2 progenies were classified on the basis of dihybrid segregation of capsule surface and branching habit. The data are presented below:

F_2 Family	Rugate capsule		Non-rugate capsule		Total
	Branched	Non-branched	Branched	Non-branched	
4,477	92	28	30	11	161
4,478	81	25	25	7	138
4,479	72	16	18	6	112
4,481	154	38	44	14	250
Total	399	107	117	38	661
Expected (9:3:3:1)	371·81	123·94	123·94	41·31	661·00

$X^2 = 4 \cdot 96$ $P = 0 \cdot 20\text{–}0 \cdot 10$

The above data show an independent assortment of the genes for capsule surface and branching habit.

SUMMARY

As a result of this investigation a new factor pair, Ru-ru, rugate-non-rugate, controlling the capsule surface character in *C. capsularis* is established.

It has also been shown that there is no evidence of linkage between the genes for capsule surface and those for its shape or between genes for capsule surface and those for the branching habit.

ACKNOWLEDGEMENTS

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ACCUMULATION AND MOVEMENT OF MINERALS IN *KODRA* (*PASPALUM SCROBICULATUM* LINN.)[1]

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Kodra (*Paspalum scrobiculatum* Linn.) is an important minor cereal crop of Kaira district in Bombay State. The importance of it is second to pearl millet (*Pennisetum typhoideum* Rich). Of the total area under *Kodra* in Bombay State, 70 per cent is occupied in Gujarat and from this 33 per cent is in Kaira district. It is a substitute for rice for middle class and poor families and was used even in well-to-do families during the days of acute rice shortage. It is richer in protein, vitamin B_1, phosphorus and other mineral matters than rice but poorer in carbohydrates.

At present, we have little information regarding the quantities of nutrients removed by *Kodra*. Before any fertilizer programme is taken up, it is necessary to know the amounts of nutrients a crop takes up. Little information is available on the rate of growth, uptake, migration and assimilation of nutrients in the tissues of this plant. The present study deals with the growth and development of *Kodra* in relation to accumulation and movement of some macro-nutrients at different stages of growth.

MATERIAL AND METHODS

Kodra was grown in rows 15 inches apart with plants spaced at 2 to 3 inches within the row. After every five lines of *Kodra*, there was a row of *tur* (*Cajanus cajan*), this being the common practice here. One row of *Kodra* adjoining the *tur* line on each side was left out to avoid the effect of this leguminous crop. Out of the remaining two rows of *Kodra*, four portions were marked out in each row leaving five plants between these portions, and samples were taken from each of these portions. Samples were collected at growth stage (30 days after sowing), preflowering stage (44 days after sowing), milk stage (55 days after sowing), dough stage (72 days after sowing) and harvest stage (95 days after sowing), when average heights of the plants were 22·0, 24·0, 28·6, 32·3, 33·1 inches respectively. A number of plants varying according to the size of plants were carefully removed with a shovel, keeping as much soil adhering to the roots as was practicable. In spite of these precautions taken, the roots of the later samples suffered some damage on account of hardness of clods formed around them. Possibly some fine rootlets were lost in most cases but the losses in earlier samples were negligible. The soil adhering to the roots was carefully washed out. When the plants were small, only leafy portion was separated from the roots, but in the preflowering stage the leaves were separated from the stem leaving the sheath with it. At the advent of the milk stage, the earhead was separated from the stem, but it was not possible to isolate the grain. At the dough and the harvest stages, the

[1] It is a part of thesis submitted by the senior author to the Sardar Vallabhbhai Vidyapeeth in partial fulfilment of requirements for M.Sc. (Agric.) degree.

grain separated from the earhead. The plants were dissected into their botanical parts. After sorting out each kind of tissue, it was cut into small pieces and a representative sub-sample of 100 gm. wherever available, or the whole plant when the weight was less, was dried to a constant weight at 70°C. in a well-ventilated oven. The material was then pulverized in a Wiley mill and the final samples were kept in tightly stoppered bottles until analysis. Nitrogen was determined by usual Kjeldahl procedure, phosphorus and calcium by the A.O.A.C. [1955] volumetric methods, potassium by following the volumetric cobaltinitrite method of Volk and Truog [1934], revised later by Volk [1941] after ashing the plant material and magnesium by volumetric method of Hardin and MacIntire [1949].

RESULTS AND DISCUSSION

Total Dry Matter

The maximum total dry matter (Table I) is manufactured between the milk and the dough stages. This trend in *Kodra* plant is similar to that observed in *Bavto* plant —*Eleusine coracana* (Linn.) Gaertn. [Khatri, 1958]. The weights of all the tissues except the empty earhead continue to increase steadily from the growth up to the harvest stage. As the grain matures, it increases in weight and at the harvest stage the increase is about 40 per cent of the weight at the dough stage.

TABLE I. WEIGHT PER *KODRA* PLANT OF DRY MATTER (gm.)

Stage	No. of days of growth	Leaf	Stem	Root	Grain	Ear-head (empty)	Total
Growth	30	1·51	..	0·13	..	..	1·64
Preflowering	44	1·71	0·34	0·21	..	0·22	2·48
Milk	55	1·98	1·13	0·25	..	1·28	4·65
Dough	72	2·20	2·03	0·28	4·02	0·70	9·23
Harvest	95	2·70	2·39	0·32	5·48	0·76	11·65

Accumulation of Nitrogen

The percentage of nitrogen in the leaf (Table II) is highest at the milk stage after which it continues to fall till the harvest. The fall is maximum between the milk and the dough stages probably due to high requirements of nitrogen by the newly developing earhead. The percentage of nitrogen in the stem and the empty earhead goes on decreasing till the harvest to meet the demand of the developing earhead. The percentage of nitrogen in the root is highest at the milk stage. It then goes on decreasing till the harvest stage. Unlike other tissues of *Kodra* plant, the grain gains nitrogen at the harvest showing the translocation from other tissue.

The percentage composition is important, but in studying the assimilation of nutrients by a plant, the total quantities of the constituents present at different stages are more important. In fixing the quantities and number of doses of a fertilizer, it is essential to find out (i) the stage in the life of the plant up to which the plant

continues to assimilate, (ii) the stage at which the highest assimilation takes place, and (iii) the total amount of the minerals which the crop requires. Hence, the amount of nitrogen per plant has been calculated. Total weight of the nitrogen per plant is highest at the harvest. This means that the plant accumulates nitrogen till the harvest. The demand of nitrogen by *Kodra* plant as a whole is greatest between the preflowering and the milk stages; only slightly less quantity is assimilated in the subsequent stage. Like the percentage of nitrogen, the per plant amount is highest at the milk stage in the leaf, then it decreases due to the translocation to other developing parts. The stem has maximum amount at the dough stage and then it decreases slightly at the harvest. The roots continue to accumulate nitrogen till the milk stage after which it remains constant. The empty earhead has the highest amount at the milk stage and then it decreases till the harvest. The grain on the contrary gains considerably at the harvest due to the translocation of nitrogen from other tissues.

TABLE II. PERCENTAGE AND WEIGHT IN GM. PER *KODRA* PLANT OF NITROGEN ON DRY WEIGHT BASIS

Stage	No. of days of growth	Nitrogen (per cent)					Wt. of nitrogen per plant (gm.)					
		Leaf	Stem	Root	Grain	Ear-head (empty)	Leaf	Stem	Root	Grain	Ear-head (empty)	Total
Growth	30	0·917	..	0·525	..	..	0·0138	..	0·0007	..	..	0·0145
Preflowering	44	0·938	0·623	0·658	..	1·722	0·0160	0·002	0·0014	..	0·0038	0·0232
Milk	55	1·281	0·553	0·665	..	1·036	0·0254	0·006	0·0017	..	0·0133	0·0464
Dough	72	0·700	0·427	0·560	0·889	0·799	0·0154	0·009	0·0016	0·0357	0·0055	0·0672
Harvest	95	0·448	0·322	0·546	0·938	0·623	0·0121	0·008	0·0017	0·0514	0·0047	0·0779

Accumulation of Phosphorus

The percentage of phosphorus expressed as P_2O_5 is given in Table III below.

TABLE III. PERCENTAGE AND WEIGHT IN GM. PER *KODRA* PLANT OF PHOSPHORUS (AS P_2O_5) ON DRY WEIGHT BASIS

Stage	No. of days of growth	P_2O_5 (per cent)					Wt. of P_2O_5 per plant (gm.)					
		Leaf	Stem	Root	Grain	Ear-head (empty)	Leaf	Stem	Root	Grain	Ear-head (empty)	Total
Growth	30	0·812	..	0·527	..	..	0·0123	..	0·0007	..	..	0·0130
Preflowering	44	0·806	0·750	0·468	..	0·775	0·0138	0·0026	0·0009	..	0·0017	0·0190
Milk	55	0·670	0·645	0·434	..	0·719	0·0133	0·0073	0·0011	..	0·0092	0·0309
Dough	72	0·657	0·620	0·428	0·719	0·688	0·0144	0·0126	0·0012	0·0289	0·0048	0·0619
Harvest	95	0·465	0·546	0·242	0·843	0·608	0·0126	0·0130	0·0007	0·0462	0·0046	0·0771

The percentage of phosphorus is highest in the leaf at the growth stage. It then steadily declines till the harvest. But the amount of phosphorus per plant in the leaf does not show any regular trend. It increases at the preflowering stage and decreases at the milk stage. It again increases at the dough stage and then falls at the harvest stage. The percentage of phosphorus in the stem is highest at the preflowering stage and then it declines up to the harvest stage, but the per plant amount shows reverse tendency, being highest at the harvest stage and lowest at the preflowering stage. Like percentage of phosphorus in the stem, the root phosphorus also declines till the harvest stage. The root phosphorus per plant increases also up to the dough stage but decreases thereafter. The grain at the harvest stage has a higher percentage as well as per plant amount of phosphorus. The plant as a whole has maximum demand of phosphorus between the milk and the dough stages.

Accumulation of Potassium

Table IV shows that the leaf and the root have continuously decreasing percentage of potassium up to the dough stage after which there is a slight increase. In the case of the stem, there is an increase in potassium up to the milk stage, then it decreases at the dough stage, but later on at the harvest it increases. Like the stem, the potassium content of the grain increases at the harvest. The percentage of potassium in the empty earhead decreases at the milk stage, but again it increases up to the harvest stage. The stem is the richest tissue of the *Kodra* plant so far as potassium is concerned, next in order come the leaf, the empty earhead, the root and the grain.

TABLE IV. PERCENTAGE AND WEIGHT IN GM. PER *KODRA* PLANT OF POTASSIUM ON DRY WEIGHT BASIS

Stage	No. of days of growth	Potassium (per cent)					Wt. of potassium per plant (gm.)					Total
		Leaf	Stem	Root	Grain	Ear-head (empty)	Leaf	Stem	Root	Grain	Ear-head (empty)	
Growth	30	2·666	..	1·782	..	..	0·0403	..	0·0023	..	..	0·0426
Preflowering	44	2·582	3·636	1·448	..	2·303	0·0442	0·0124	0·0029	..	0·0051	0·0646
Milk	55	1·842	3·672	1·224	..	1·224	0·0365	0·0415	0·0031	..	0·0150	0·0961
Dough	72	1·454	3·503	1·212	0·558	1·660	0·0320	0·0711	0·0034	0·0224	0·0116	0·1405
Harvest	95	1·648	4·582	1·230	0·703	2·448	0·0445	0·1095	0·0037	0·0385	0·0186	0·2148

It is found that while the percentage of potassium decreases in the leaf, the amount per plant increases up to the preflowering stage, then goes on decreasing up to the dough stage and again increases at the harvest stage. In the stem, the root, the grain, and the empty earhead the content of potassium goes on increasing up to the harvest stage. The maximum accumulation of potassium in the plant as a whole takes place between the dough and the harvest stages. Thus, while the demand of nitrogen in *Kodra* plant is greatest during the earlier life-cycle of the plant, the requirement of potassium is maximum between the dough and the harvest stages. In *Kodra* plant when the nitrogen requirement is greatest, the potassium need is least.

Accumulation of Calcium

The percentage of calcium is, in general, less than that of potassium. While the percentage of potassium in the leaf steadily declines up to the harvest stage, the percentage of calcium in the leaf goes on increasing up to the harvest stage (Table V). The grain and the empty earhead follow the same trend. It is highest in the stem and the root at the dough stage and then it decreases up to the harvest stage.

TABLE V. PERCENTAGE AND WEIGHT IN GM. PER *KODRA* PLANT OF CALCIUM ON DRY WEIGHT BASIS

Stage	No. of days of growth	Calcium (per cent)					Wt. of calcium per plant (gm.)					Total
		Leaf	Stem	Root	Grain	Ear-head (empty)	Leaf	Stem	Root	Grain	Ear-head (empty)	
Growth	30	0·378	..	0·336	..	..	0·0057	..	0·0004	..	..	0·0061
Preflowering	44	0·403	0·208	0·312	..	0·208	0·0069	0·0007	0·0007	..	0·0005	0·0088
Milk	55	0·454	0·208	0·323	..	0·205	0·0090	0·0024	0·0008	..	0·0026	0·0148
Dough	72	0·522	0·256	0·378	0·106	0·259	0·0115	0·0052	0·0011	0·0043	0·0018	0·0239
Harvest	95	0·541	0·240	0·163	0·118	0·314	0·0146	0·0057	0·0005	0·0064	0·0024	0·0296

The per plant weight of calcium is highest at the harvest stage in the leaf, the stem and the grain, and at the milk stage in the empty earhead. In the root it is highest at the dough stage, and lowest at the harvest. The leaf requirement of calcium is more than that of any other part of *Kodra* plant. Here we observe a difference between the calcium and potassium requirements of the leaf and the stem. The stem of *Kodra* plant assimilates the maximum amount of potassium, while the leaf takes up the highest amount of calcium as observed in *bavto* plant [Khatri, 1958]. The highest accumulation in the stem takes place between the milk and the dough stages, and in the leaf between the dough and the harvest stages. Like potassium, the calcium content of the plant as a whole is highest at the harvest stage. Like *bavto* (*loc. cit.*), the *Kodra* plant as a whole has the greatest demand for calcium between the milk and the dough stages. The grain accumulates significantly large amount of calcium even after the dough stage. This observation in case of *Kodra* plant is similar to that observed in *bavto* but is not in accordance with that observed by Mehta and Shah [1958] in pearl millet, in which case the accumulation of calcium at the dough and the harvest stages was almost equal. This shows that in *Kodra* plant with gain in carbohydrates of the grain, there is a considerable gain in calcium content also.

Accumulation of Magnesium

The percentage of magnesium in all the tissues of *Kodra* plant is highest at the initial stage and decreases as the plant matures (Table VI).

The per plant amount of magnesium is highest at the harvest stage in the leaf and the grain, and at the milk stage in the root and the empty earhead. In the stem,

the percentage as well as the amount of magnesium per plant is highest at the pre-flowering stage. The plant as a whole assimilates magnesium up to the dough stage, the maximum accumulation taking place between the milk and the dough stages.

TABLE VI. PERCENTAGE AND WEIGHT IN GM. PER *KODRA* PLANT OF MAGNESIUM ON DRY WEIGHT BASIS

Stage	No. of days of growth	Magnesium (per cent)					Wt. of magnesium per plant (gm.)					
		Leaf	Stem	Root	Grain	Ear-head (empty)	Leaf	Stem	Root	Grain	Ear-head (empty)	Total
Growth	30	0·305	..	0·441	..	..	0·0046	..	0·00055	..	..	0·00515
Preflowering	44	0·266	0·252	0·399	..	0·205	0·0046	0·00085	0·00064	..	0·00046	0·00655
Milk	55	0·241	0·237	0·376	..	0·137	0·0048	0·0027	0·00096	..	0·00176	0·01022
Dough	72	0·298	0·200	0·298	0·109	0·093	0·0066	0·0041	0·00084	0·0044	0·00065	0·0166
Harvest	95	0·255	0·133	0·064	0·102	0·109	0·0069	0·0032	0·00020	0·0056	0·00083	0·0167

Accumulation of Dry Matter and Nutrients

Table VII below gives the total accumulation of dry matter and nutrients removed per acre.

TABLE VII. TOTAL ACCUMULATION IN POUNDS PER ACRE IN *KODRA* (DRY WEIGHT BASIS)

Stage	No. of days of growth	Dry matter	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Growth	30	673	5·96	5·34	17·51	2·51	2·14
Preflowering	44	1,022	9·58	7·40	26·55	3·62	2·71
Milk	55	1,909	19·15	12·70	39·50	6·08	4·20
Dough	72	3,794	27·50	25·44	57·75	9·52	6·82
Harvest	95	4,787	31·89	31·69	87·05	12·17	6·88

The maximum production of dry matter takes place between the milk and the dough stages which can be called the grand period of development. During this period, slightly less than one ton of dry matter is synthesized. This represents heavy carbon assimilation with absorption of about 8 lb. of nitrogen, 13 lb. of phosphoric acid, 18 lb. of potassium, and 3 lb. each of calcium and magnesium. For total dry matter production of about two tons per acre, about 32 lb. each of nitrogen and phosphoric acid, 87 lb. of potassium, 12 lb. of calcium, and 7 lb. of magnesium are required. On equal total dry matter basis, *Kodra* removes as much nitrogen as that removed by *bavto* plant [Khatri, 1958]; calcium and magnesium are less removed.

TABLE VIII. CATION CONTENT OF *KODRA* TISSUES AT VARIOUS STAGES OF GROWTH IN M.E. PER 100 GM. ON DRY WEIGHT BASIS

Stage	Leaf				Stem				Root				Grain				Earhead (empty)			
	K	Ca	Mg	Total	K	Ca	Mg	Total	K	Ca	Mg	Total	K	Ca	Mg	Total	K	Ca	Mg	Total
Growth	68·3	18·9	25·4	112·6	..	..	..	..	45·7	16·8	36·7	99·2	..	..	..	..	..	..	..	..
Preflowering	66·2	20·1	22·1	108·4	93·2	10·4	21·0	124·6	37·1	15·6	33·2	85·9	..	..	..	..	59·0	10·4	17·0	(86.4)
Milk	47·2	22·7	20·0	89·9	94·1	10·4	19·7	124·2	31·4	16·1	31·3	78·8	..	..	..	..	31·4	10·2	11·4	53·0
Dough	37·3	26·1	24·8	88·2	90·0	12·8	16·6	129·4	31·0	18·9	24·8	74·7	14·3	5·3	9·0	28·6	42·5	13·0	7·7	63·2
Harvest	42·2	21·1	21·2	84·5	117·7	12·0	11.0	140·7	31·5	8·1	5·3	44·9	18·0	5·9	8·5	32·4	62·7	15·7	9·0	87·4

Cation Contents in m.e. per 100gm.

As in case of *bavto* plant (*loc. cit.*), the potassium concentration in any tissue of *Kodra* plant is greater than that of calcium or magnesium ions at the corresponding stage of development (Table IX). The total cation concentration of the stem is higher than that of any other organ at the corresponding stage. In *Kodra* plant, higher cation concentration is observed in stem and not in the leaf as is observed in *bavto* plant (*loc. cit.*). In the leaf and the root, the total cation concentration decreases as the plant develops, but in the stem and the grain it increases, showing the translocation of cations to the grain as the plant develops.

Cationic Ratio

Potassium, calcium and magnesium ions have a specific function over and above some common functions [Lucas and Scarseth, 1947]. For understanding the functions of cations in plant, the study of the cationic ratio is as important as the study of absolute weights of these cations. Cationic ratios ($\frac{Ca+Mg}{K}$) of different tissues have, therefore, been calculated. They are given in Table IX.

TABLE IX. ($\frac{Ca+Mg}{K}$) IN EQUIVALENTS IN *KODRA* TISSUES

Stage	No. of days of growth	Leaf	Stem	Root	Grain	Earhead (empty)
Growth	30	0·66	...	1·17	..	..
Preflowering	44	0·64	0·34	1·32	...	0·46
Milk	55	0·90	0·32	1·49	..	0·69
Dough	72	1·37	0·33	1·41	1·00	0·48
Harvest	95	1·14	0·20	2·30	0·80	0·43

The ratio is not constant in different parts of the plant at different stages of growth, the ratio being highest in the root and lowest in the stem. The ratio decreases as the plant grows in the case of the stem, the grain and the empty earhead while it increases steadily in the leaf and the root at the harvest stage. As compared to all other tissues of *Kodra* plant, the ratio for the stem is very low showing that potassium ions, like those in *bavto* plant, have a more dominant role in the growth of the stem than in other tissues. The ratio for the leaf and the root is highest and hence it can be inferred that calcium and magnesium ions have a more prominent role than potassium in the growth of the leaf and the root than in other tissues.

Translocation of the Elements within the Plant during the Growth

To study the movement of the elements in the different tissues of the plant, period between the dough and the harvest stages has been chosen (Table X). It is found that the leaf, the stem and the empty earhead together lose 0·0051 gm. of nitrogen, while the root remains practically unaffected. The plant as a whole gains 0·0107 gm. of nitrogen. This means that, though a considerable amount of nitrogen migrates

in the direction of the grain as it matures, there is not much loss in other tissues, the amount transported being more than replenished by the nitrogen drawn from the soil. This trend in *Kodra* plant is exactly similar to that observed in *bavto* plant. The grain and the stem together gain 0·0177 gm. of phosphoric acid, while the leaf, root and the empty earhead together lose 0·0025 gm. due to the translocation to the developing grain. The plant as a whole gains 0·0152 gm. of phosphorus. All the tissues of *Kodra* plant except root gain potassium. The grain, the leaf, the stem and the empty earhead on the whole gain 0·0741 gm. of potassium while the root loses 0·0027 gm. The net effect on the plant as a whole is gain of 0·0713 gm. Translocation of calcium is similar to that of potassium, the net gain by the whole plant being 0·0057 gm. of calcium. In the case of magnesium there is a gain of 0·00168 gm. in the grain, the leaf and the empty earhead taken together, while the stem and the root collectively lose 0.0015 gm, i.e. there is redistribution of magnesium among the tissues but practically no absorption from the soil.

TABLE X. BALANCE ACCOUNT OF NITROGEN, PHOSPHORUS, POTASSIUM, CALCIUM AND MAGNESIUM IN THE TISSUES OF THE *KODRA* PLANT (weight in gm. per plant)

Element	Date and stage	Grain	Leaf	Stem	Root	Earhead (empty)	Total
Nitrogen	October 3, dough	0·0357	0·0154	0·0087	0·0016	0·0055	0·0672
	October 26, harvest	0·0514	0·0121	0·0077	0·0017	0·0047	0·0779
	Gain or loss	+0·0157	–0·0033	–0·0010	+0·0001	–0·0008	+0·0107
Phosphorus	October 3, dough	0·0289	0·0144	0·0126	0·0012	0·0048	0·0619
	October 26, harvest	0·0462	0·0126	0·0130	0·0007	0·0046	0·0771
	Gain or loss	+0·0173	–0·0018	+0·0004	–0·0005	–0·0002	+0·0152
Potassium	October 3, dough	0·0224	0·0320	0·0711	0·0034	0·0116	0·1405
	October 26, harvest	0·0385	0·0445	0·1095	0·0007	0·0186	0·2118
	Gain or loss	+0·0161	+0·0125	+0·0385	–0·0027	+0·0070	+0·0713
Calcium	October 3, dough	0·0043	0·0115	0·0052	0·0011	0·0018	0·0239
	October 26, harvest	0·0064	0·0146	0·0057	0·0005	0·0024	0·0296
	Gain or loss	+0·0021	+0·0031	+0·0005	–0·0006	+0·0006	+0·0057
Magnesium	October 3, dough	0·0044	0·0066	0·0041	0·0008	0·00065	0·0166
	October 26, harvest	0·0056	0·0069	0·0032	0·0002	0·00083	0·0167
	Gain or loss	+0·0012	+0·0003	–0·0009	–0·0006	+0·00018	+0·00018

SUMMARY

In *Kodra* plant, the dry matter increases continuously up to the harvest stage and maximum production takes place between the milk and the dough stages.

Almost continuous absorption of all the elements takes place during all the stages of growth and development in this crop.

Maximum accumulation of nitrogen takes place between the preflowering and the milk stages of phosphorus, calcium and magnesium between the milk and the dough stages, and of potassium between the dough and the harvest stages.

At all the stages of growth, the percentage of potassium is greater in the stem of *Kodra* plant than in other tissues. The percentage of calcium and magnesium is higher in the leaf and the root than in other parts. The grain is richer in nitrogen and phosphoric acid than the other tissues.

The amounts of nutrients removed by *Kodra* crop producing about two tons of dry matter per acre are: nitrogen and phosphorus each 32 lb., potassium 87 lb., calcium 12 lb., and magnesium 7 lb.

The highest total cation concentration is in the leaf of this plant. Potassium ion concentration in any tissue of this crop is greater than that of calcium or magnesium ions at the corresponding stage of development. Cationic ratio $\frac{(Ca+Mg)}{K}$ is lowest for the stem and highest for the leaf and the root, showing a more prominent role of potassium in the stem while that of calcium and magnesium in the leaf and the root.

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A REVIEW OF THE FODDER AND GRASSLAND RESOURCES WITH SUGGESTIONS FOR THEIR EARLY IMPROVEMENT

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Cattle play a vital role in the economic structure of the country. So long as the basis of Indian economy is agriculture, cattle will remain one of the most important factors in national economy. According to the livestock census of 1951, it has been estimated that there are, in India, about 198 million cattle, by far the largest number in any region of comparable size in the world. This constitutes about a quarter of world's bovine population. The nutritional status and efficiency of both milch and draught cattle in India are the lowest compared to the cattle in Europe, the U.S.A., New Zealand or Australia. The milk production per cow is only one-tenth of that produced by a cow in Denmark, and one-fifth of the production in the U.S.A. and Australia. The ordinary village cows can produce 50 per cent more milk, if they are well fed on adequate ration. The Royal Commission on Agriculture [1928] stated, "No substantial improvement by improved breeding methods is possible until cattle can be fed better". Even in the present underdeveloped state, the estimated contribution of livestock to Indian economy is of the order of three to four thousand crores of rupees. The present neglected state of our cattle should be improved by proper feeding, breeding and management, so that this vast potential wealth of cattle can make valuable contribution in increasing the national wealth of the country and in the standard of living of the people.

In most of the agriculturally advanced countries, fodder production, pasture and range management have received great attention as these are considered an asset for economic return from the cattle. In India, only 4 per cent of total acreage of cultivated area is under fodder crops as compared with 25 per cent in the U.K. and 60 per cent in the U.S.A. In India, the cultivable area devoted to fodder production is 11·2 million acres and that open to grazing 5·12 million. The total area under forests is about 6·4 million, but only a small percentage of cattle have access to the forest range-lands. The small area devoted to fodder crops is not due to the fact that cultivator is not aware of the needs of cattle, but because of the pressure of population on the land and pressing need for the production of food crops in adequate quantities. In order to feed the present population of cattle adequately, it is estimated that 40·28 million tons of concentrate feed and 932 million tons of fodder are annually needed. The actual production, however, is only 13·76 million tons of concentrates and 798 million tons of fodder. This leaves a very wide gap between requirement and availability. Therefore, there is an urgent need of finding ways and means of augmenting the present fodder resources to stabilise the animal husbandry in the Indian economy.

PRESENT FODDER PRODUCTION AND GRAZING RESOURCES

Fodder Crops for Arable Lands

Broadly, the fodder crops of arable lands are legumes, non-legumes and perennial grasses.

1. *Legumes*: The cultivation of legumes for fodder purposes is confined to regions where ample irrigation facilities are available and this too is restricted to large holdings, Government Livestock farms, Dairy farms, etc. Some of the legumes widely cultivated as fodders and the State where these are grown are as follows:

Berseem (*Trifolium alexandrinum*) .. Punjab, Uttar Pradesh, Rajasthan, Bihar and Madhya Pradesh.

Lucerne (*Medicago sativa*) .. All over India except regions receiving heavy rainfall.

Cowpeas (*Vigna sinensis*) .. Punjab, Uttar Pradesh, Madhya Pradesh.

In addition to the above legumes, the following are the less important legumes cultivated in one or the other part of the country:

Senji (*Melilotus parviflora*), *Methra* (*Trigonella foenumgraecum*), *Pillipesara* (*Phaseolus trilobus*), *Moth* (*Phaseolus aconitifolius*), *Val* (*Dolichos lablab*), *Kulthi* (*Dolichos biflorous*), *Khesari* (*Lathyrus sativus*), field peas (*Pisum arvense*), and Soyabean (*Glycine max*).

2. *Non-leguminous fodder crops:* Maize (*Zea mays*), *Jowar* (*Sorghum vulgare*) and oats (*Avena sativa*) are the other fodder crops. They provide excellent herbage both for soiling and silage purposes. These are mostly cultivated in the Punjab, Uttar Pradesh, Madhya Pradesh, Bombay and Madras States.

3. *Perennial grasses:* The important perennial grasses now under cultivation in India are Napier (*Pennisetum purpureum*), Guinea (*Panicum maximum*), Para (*Brachiaria mutica*), Rhodes (*Chloris gayana*) and Sudan (*Sorghum vulgare* var. *sudanensis*). Their cultivation is largely confined to Government or private dairy farms.

Besides the green forage, the dry roughage is provided by the by-products of most of the cereals and pulses such as wheat, paddy, *jowar*, *bajra*, gram, peas, surgarcane tops, etc.

Grasslands

The majority of cattle have to depend on grazing provided on fallow lands, field bunds, uncultivated land, cultural waste lands, etc. At present the so called pastures are carrying three or more animals per acre for most part of the year. Since the carrying capacity of these pastures is extremely low, these are just serving the mere purpose of exercising grounds. The actual period for grazing is confined to about five months in the year and the cattle suffer from acute shortage of fodder in the remaining months when they sometimes even face semi-starvation. There being no control on grazing, the deterioration of grasslands is rapidly proceeding apace. This very early and continuous overgrazing, practised year after year, has resulted in depletion of vegetation and consequently has very much reduced the carrying capacity of the pastures. The nutritive pasture grasses have given place to hardy, poor grasses which are capable of withstanding overgrazing. Excessive overgrazing, particularly in hills and submontane regions, by very large herds, have denuded the lands and left them exposed to the erosive action of rains. In some areas the burning of grassland

to provide fresh young growth, cutting of herbage and fuel have further led to the deterioration in the botanical composition of grasslands from perennial species to annual species. It has further resulted in yielding poor fodder and providing less protection to the eroding soils.

Forest Grazing

At present grazing in State forests yields about Rs. 95 lakhs of revenue, it provides fodder for about 25 million cattle. The grazing is confined to the outer fringes of the forests, which are in a degraded condition owing to centuries of unwise grazing. The position in some of the States with regard to forest grazing is as under:

Bombay: Some work has been done in dry tracts by the Agricultural Department in regulating number of animals for grazing, fencing, provision of watering facilities, etc.

Madras: There is heavy and unregulated grazing.

Punjab: There is heavy grazing at the foot of the hills which results in heavy soil erosion every year.

Uttar Pradesh: Only a fraction of cattle population use forest for grazing.

From the above account it is obvious that uncontrolled grazing has led to very deteriorated condition of forest rangeland and that the facilities for grazing are very limited.

INCREASING FODDER PRODUCTION AND REHABILITATING GRASSLANDS

(A) *Introducing Fodder Crops in Mixed Farming*

There is a great need to plan the agricultural policy of the country in such a way as to make the best possible use of land resources. Besides planning for immediate increased production there is need to maintain fertility of the soils and improve it. The well-being of soil is fundamental to the healthy development of agriculture and animal husbandry in India. Mixed farming offers wide possibilities of adoption. Introduction of leguminous fodder crops in the crop husbandry will not only increase the return from animals but also improve soil fertility. The by-product viz., manure from animals enables production of cash crops. The combination of fertilization programme of nitrogen to cereals and cash crops, and phosphate to legumes augments production of foodgrains, feeds, fodders, cash crops, and milk and milk products. Experiments on mixed farming conducted in several States of the country have conclusively shown that mixed farming is more productive than arable farming.

1. *Ley in mixed farming:* Introduction of leys consisting of grasses and legumes, which can stand grazing in mixed farming is another way of improving production of more nutritious fodder from the land. The grass-legume leys form the pivot of fodder around which all other crops are rotated systematically all over the field. The leys serve dual purpose of fodder production and maintenance and improvement of soil fertility. In Australia, subterranean clover pastures are maintained for five to six years and thereafter 'four ton crop' of rice is raised. Similar system has been developed in all dairy farming countries of the world.

The experiments at the Indian Agricultural Research Institute on role of leys in mixed farming have indicated that inclusion of grass-legume ley of one, two or three years duration maintain a higher level of soil fertility as compared to continuous

cereal rotation. Rhodes and lucerne ley appears to have a future as a dual purpose fodder. Mixed farming is a normal way of husbandry in most parts of this country. Therefore, the cultivators can be convinced by proper demonstration of the advantages of integrating animal husbandry and dairying with suitable introduction of leys into their cropping pattern. There are certain regions in Bombay State where rice fields are left under natural grasses for a period varying from two to as many as six or eight years. These are ideal conditions for introducing short and long duration leys. In most of these regions winter annual grasses like *Phalaris minor* (chidia bajra), *Secale cereale* (Russian rye grass), *Loliums* (Rye grasses) in combination with such legumes as *Vicia sativa* (Vetch), *Medicago hispida* (bur clover), *Melilotus alba* (Hubam clover) and *Phaseolus trilobus* (Pillipesara) are worth trying.

2. *Legumes in mixed farming:* Besides, the legumes such as berseem, cowpeas, mucuna, etc. can easily be fitted into the existing pattern of agriculture. These crops supply protein-rich herbage and also improve the fertility status of the soil.

The introduction of berseem (*Trifolium alexandrinum*) under irrigated conditions in northern India has solved the problem of fodder during the winter months and up to May in summer. The maximum yield of green fodder can be obtained by sowing the crop from late September to the middle of October and fertilizing with a dose of phosphate up to 120 lb. P_2O_5 per acre combined with regular irrigation at 12 days intervals.

Phosphate application to berseem at the rate of 80 lb. increased berseem fodder yield by 30-40 per cent and the subsequent crop of rice did not need any nitrogenous fertilization upto the extent of 40 lb. N per acre. In an experiment, conducted at the Indian Agricultural Research Institute, it was found that the yields of cereal crops such as maize and wheat increased considerably following berseem manured with phosphate. In another experiment where berseem was grown in rotation with cowpeas and wheat, chemical analysis of the soils showed significantly higher content of nitrogen and organic matter where it was fertilized with superphosphate.

Lucerne (*Medicago sativa*) is another valuable perennial legume which supplies protein-rich, green fodder from November to July. It has also shown response to phosphatic fertilizers. *Senji* (*Melilotus parviflora*) has low water requirements compared to berseem. As *senji* is fairly drought resistant, its cultivation can be extended under rain-fed conditions and as a catch crop in the paddy areas where soils remain fairly wet after harvest of the crop.

Hubam clover (*Melilotus alba*) is a close relative of *senji* (*M. parviflora*). The crop is fairly tolerant to drought and remains green till June, giving over 350 md. of green fodder in three cuttings. The grand period of growth coincides with the harvesting period of wheat. Preliminary tests have shown that when sown in mixture with wheat, two cuttings of clover can be obtained after the harvest of wheat. This makes it possible to get fodder as well as green manure crop and yet not lose any grain or cash crop. Further experiments on this aspect are in progress at the Institute.

Cowpeas (*Vigna sinensis*) grows well in association with maize for fodder. This not only increases the fodder yield but also makes it richer in protein. The crop succeeding this mixture is also benefitted by the nitrogen fixed by it. When grown in association with maize or *jowar*, a thick stand of crop is obtained which helps in checking erosion especially in hilly regions. The yield of cowpeas can be increased on phosphate

deficient soils by a dressing of 40-60 lb. P_2O_5. By fertilizing with phosphate the nutritive value of the fodder is also improved. Where the status of phosphate in the soil is high, it does not pay to fertilize the crop. Crops under irrigated conditions can be sown as early as beginning of March to supply fodder during the scarcity periods of May and June. The early variety K 397 has high fodder yield potential. It can be grown all the year round in Bengal and parts of Bihar and Orissa. The average yield is about 250 md. of green fodder per acre.

Pillipesara (*Phaseolus trilobus*) is the most popular of leguminous fodders in South India. It is sown in November in the standing paddy crop and yields about 200 md. in two to three cuttings. It is a nutritious fodder and its cultivation should be encouraged.

3. *Non-legumes in mixed farming:* The dried stalks of *jowar kadbi* are the main feed over a greater part of India. This crop is cultivated both under irrigated and rainfed conditions. Under irrigation it responds favourably to nitrogenous fertilizer. A dose of 50 lb. of nitrogen increases the yield by 100 to 150 md. per acre. *Jowar* (*Andropogon sorghum*) is cultivated in mixture with legumes like cowpeas, *moth*, *mung* and *val*. But by fertilization the yield of 350-450 md. can be obtained on loamy and clayey soils. Its sowing can be so adjusted that the supply of green fodder is available from May to September. In the system of mixed farming, particularliy in the dairy districts of Bombay State, it occupies a privileged position. *Sundia Jowar* Strain 273 gives high out-turn. The selections from Sirsa, J. 20 and J. 21, are sweet varieties and are much relished by cattle. The analysis of milk records of the Tharparkar herd has shown that the cows maintained a high-rate of milk production during the periods when *jowar* was fed to them.

Maize (*Zea mays*) is more leafy and nutritious fodder and is much safer than *jowar* to feed in its early stages of growth. Experiments have shown that maize when grown after phosphate-fertilized berseem, gives much higher yield than otherwise. But maize following sugarcane, cotton or wheat must receive a dressing of three to five tons of F.Y.M. and 60 lb. nitrogen to increase its yield. This crop forms good mixture with legumes like cowpeas, mucuna *guar*, *moth*, etc. With heavy fertilization under irrigated conditions a yield of 500 md. can be obtained alone or in mixture with legume. Its dry stalks are less nutritious than those of *jowar kadbi*. The other important non-leguminous fodder crops are *bajra* (*Pennisetum typhoideum*) and oats (*Avena sativa*). *Bajra* is an important fodder in the arid regions. A promising variety T. 55, evolved by the Punjab Department of Agriculture is quite high yielding. Fodder oats varieties recommended by I.A.R.I. are N.P. 1, N.P. 2 and N.P. (Hybrid) 27. These oat varieties can go into mixed farming practice for feeding stock.

4. *Catch crops in mixed farming:* The introduction of catch crops is another means towards this end. The fodder resources to a measurable extent can be increased immediately by the introduction of short duration catch crops of fodder. Studies conducted at the Institute have shown that such crops as *Vicia sativa* (Vetch), *Medicago hispida* (Bur clover), *Melilotus alba* (Hubam clover), etc. can be well recommended for inclusion as catch crops. These could be very conveniently introduced in the cultivavator's rotation. Thus for example in paddy growing area, these crops could occupy the field after the paddy crop is harvested in December. Most of these legumes possess the valuable quality of regeneration from their own seeds which fall down in

the field giving fodder to the cattle and improving the soil fertility. Mention of such catch crops as cowpeas, sudan grass, *guar*, soyabean, *moth*, *swank*, *khesari*, *Methra*, etc. has already been made. These fodder crops help the cultivator in tiding over the periods of fodder scarcity and ensure continuous supply of forage.

5. *Perennial grasses:* The introduction of high-yielding perennial grasses in mixed farming in areas located close to urban localities can ensure continuous supply of low cost green fodder for greater part of the year. The following are the grasses which have proved useful for this purpose at the Institute:

Napier (*Pennisetum purpureum*), Guinea (*Panicum maximum*), Para (*Brachiaria mutica*), Kazungula (*Setaria sphacelata*) and Rhodes (*Chloris gayana*). All these grasses are for irrigated conditions and give very high yields under sewage irrigation. The yields recorded in case of these grasses are presented below:

	Average yield (md./acre)	Sewage irrigation
1. Para	2,250	
2. Napier	14,00	–do–
3. Guinea	1,350	–do–
4. Kazungula	1,130	Irrigated
5. Rhodes	550	–do–

The sewage of large towns and cities can very profitably be utilized for production of fodders. Perennial high yielding grasses can be introduced in such localities.

Creating Reserves of Fodders

The scientific methods of hay making and ensilage should be made popular amongst farmers. The surplus fodder of *jowar*, *bajra* and grasses can be converted into silage, and berseem, lucerne and other legumes into hay. Excellent hay is produced by curing berseem on wires. Berseem is usually surplus to the requirements in the months of March-April. This can be preserved as silage. Oat straw with berseem in the ratio of 3:1 by volume or green berseem with green oats in proportion of 3:1 by volume makes a good silage. These reserves will check any wastage and will be a source of fodder in times of scarcity and drought.

Improvement of Grasslands

1. Grasslands constitute the major source of fodder supply in India. The village pastures and grazing grounds can be improved only if there is drastic reduction in the duration and intensity of grazing. The present yielding capacity and botanical composition of the grasslands can be maintained if the stocking rate could be limited to one animal per three acres for four to five months, whereas the present pastures are carrying three or more animals per acre for most of the year. The village grazing ground requires complete protection from year-long grazing and needs to be cleared of scrub and other undesirable plants. These grazing areas should be treated in such a way so as to promote the revival of nutritious and palatable grass species which were eliminated by excessive grazing in the past. It may require reseeding of both grasses and legumes suitable for pasture lands. They should be manured and fertilized to supply plant nutrients, harrowing and weeding, etc. could be undertaken where feasible. This process of renovation is essential for deteriorated pastures.

Such measures can be introduced with the cooperation of the village *panchayats* rather than by any enforcement of regulations or enactments.

2. Another source of fodder supply is rangelands which on improvement can meet a great deal of the need of the cattle. Good grasses occur naturally in most of these areas, but are never predominating because of high intensity of grazing. They can be induced to reappear, by natural processes, to make a good contribution to India's grazing resources if they are permitted to seed at regular intervals. Efficient grazing management can go a long way to regenerate these pastures. This consists in the manner of grazing the correct number of livestock for the requisite number of days and in the season which favours optimum growth as well as utilization of the desirable pasture plants. Grasses are a great national asset and efforts should be made for protecting and utilizing them properly.

3. The lands which are at a very low level of production (sub-marginal) and have poor annual production potential such as *usar* lands, waterlogged and marshy areas, desert regions, etc. can be converted into good grazing areas by artificially reseeding with adapted improved strains of perennial grasses and legumes. The waste lands in the villages, field bunds and banks of ponds can also be utilized for growing suitable perennial grasses. There are large tracts (about 90,000 sq. miles of desert) in India which owing to continuous erosion for the past hundreds of years are lying almost unused. Here the climatic conditions are unsuitable for development of forests, and the only course open is the establishment of grasses and legumes. It is now universally recognised that grasses and legumes help in building up fertility, and protecting the soil from ravages of erosion. In selecting species for this purpose priority is to be given to those grasses and legumes which protect the soil from erosion, and can be well utilised for regulated grazing of sheep and cattle.

4. There are about 80,000 square miles open to grazing in the forests but only a very small percentage of the cattle use forest grazing. At present the vast potential wealth of herbage in the forests remains unutilised owing to lack of proper facilities of transport. If this single source is properly tapped the problem of present fodder scarcity can be solved to a great extent. The fodder resources of forests can be further increased by:

(i) Scientific management of grazing of forest ranges.
(ii) Stopping of uncontrolled and unplanned fires.
(iii) Preservation and storage of surplus herbage for use during dry season.
(iv) Reseeding of 'grass and legume' species appropriate to the site where there is insufficient vegetation.

Exploring New Herbage Plants

More than 3,000 herbage plant-types both from indigenous and exotic sources have been studied in the Agrostology Section, Division of Agronomy, of the Indian Agricultural Research Institute, New Delhi. The zonal adaptability of the material has also been determined through coordinated trials at centres representing different agro-climatic conditions. Some of the most useful species as revealed through trials for the purpose of pasturage, soilage or soil conservation are classified below according to their climatic adaptation.

Zone I, (semi arid): (rainfall 10-20 in.)	*Grasses*	*Eleucine flagillifera, Elyonurus hirsutus, Cenchrus setigerus.*
Zone II (sub-humid); (rainfall 20-40 in.)	*Grasses*	*Cenchrus ciliaris; Brachiaria brizantha; Chloris gayana; Dichanthium annulatum; Panicum antidotale; Panicum maximum* (thin guinea); *Panicum coloratum; Panicum repens; Urochloa spp.; Urochloa mosambicensis.*
	Legumes	*Pueraria hirsuta; Phaseolus lathyroides; Dolichos lablab; Mucuna cochinchinesis; Desmodium purpureum; Alysicarpus rugosus Desmodium scoparius.*
Zone III (humid) (rainfall over 40 in.)	*Grasses*	*Setaria sphacelata; Brachiaria mutica; Chloris gayana; Cynodon plectostachyum Pennisetum clandestinum; Urochloa spp.; Urochloa mosambicensis.*
	Legumes	*Pueraria phaseoloides; Gylcine javanica; Centrosema pubescens; Indigofera endecaphylla; Mucuna cochinchinensis.*

Some of the outstanding grasses and legumes for soil conservation and forage purposes are described below:

Pueraria hirsuta (Kudzu): A perennial legume, provides an excellent nutritive fodder under wide range of soil and climatic conditions. It provides a rapid and thick vegetative cover to the soil beneath, and owing to the rooting habit of the vine, the soil is protected from the crosive action of rain and water. *P. phaseoloides* (tropical kudzu) is the type suited to warm and humid regions.

Low growing perennial grasses: These are *Cynodon plectostachyum, Bothriochloa insculpta, Panicum repens, Pennisetum clandestinum,* and *Urochloa spp.* They firmly root at nodes and owing to vigorous growth cover the soil quickly and spread over extensive areas in a single season.

Semi-erect perennial grasses: In this group are included *Chloris gayana* (giant rhodes) and *Urochloa mosambicensis.* These are quite tolerant to drought and growth is quite vigorous under humid or irrigated conditions.

Bunchy perennial grasses: The important grasses in this group are *Cenchrus ciliaris, Brachiaria brizanthd, Dichanthium annulatum, Panicum antidotale, Panicum coloratum,* and *Panicum maximum* (thin guinea). They attain a height of three to five feet and are highly tolerant to drought. They show early spring growth and quick recovery after cutting.

Grasses for saline and waterlogged soils: Brachiaria mutica (para grass) and *Chloris gayana* (Rhodes) can be used for reclaiming alkaline lands. They flourish well under waterlogged conditions.

SUMMARY

The present fodder position is far from satisfactory. Any improvement in the existing condition of livestock cannot be brought about without making adequate provision for fodder supply to the cattle. This serious problem of fodder shortage

can be tackled through the close cooperation of the Agriculture Departments, Soil Conservation Boards and Forest Departments in the States.

The following steps can go a long way in easing the situation of fodder scarcity:

1. (i) In the mixed farming which is generally practised by a large number of farmers, suitable crop rotations in which fodder crops especially legumes are included should be introduced to suit different soil and climatic regions and cropping patterns. (ii) The use of leguminous 'catch crops' be made popular especially in paddy tracts. The cultural and manurial requirements of forage crops should be worked out. (iii) The introduction of leys in mixed farming both under irrigated and rainfed conditions should be encouraged. The leys should be suitably fertilized. The grazing by cattle at site will add to the nutrient status of the soil. (iv) Arrangements should be made for supplying to the cultivators seed and planting material of the recommended fodder crops and grasses. (v) Encouragement may be given to the cultivator to put in a fixed percentage of his land under fodders. This can be in the form of rebate in the purchase of seeds, fertilizers or water charges, etc.

2. The efficient use of grasslands can be only made if the duration and intensity of grazing is regulated. This can be determined by grazing according to the carrying capacity and the sound management practices. Reseeding of superior strains of herbage plants may be taken up, wherever feasible. Fertilizing by top dressing where conditions permit will increase out-turn per acre. Indiscriminate burning of grasslands should be stopped.

3. The sub-marginal, waste lands, and areas which are constantly eroded by wind or water may be planted or seeded with such grasses and legumes, which check erosion and provide ample grazing material.

4. Forest range land can provide supplemental hay and pasturage; provided they are managed and looked after properly.

5. The scope of research on pasture grasses and legumes and ley farming practices should be widened by establishing Pasture Land Research Stations in various agro-climatic regions of the country.

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CHANGES IN NITROGEN AND ORGANIC MATTER CONTENTS OF SOIL ASSOCIATED WITH THE GROWTH OF SOME SUMMER WILD LEGUMES

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Allan [1915] observed that when *Cassia occidentalis*, a wild legume, and sunnhemp were used as green manures for wheat, the former gave significantly higher yields of wheat for a considerable period of time. Utilisation of wild legumes for green manuring purposes and of their seeds as manures has been advocated by Idnani and Chibber [1953, 1956]. Little information is available, however, regarding contribution of nitrogen and organic matter to soil by wild legumes growing under natural conditions.

Alway and Pinckney [1909] attempted to make an estimate of the gains of nitrogen by soil from the growth of wild legumes under prairie conditions, and suggested that the growth of the plants may account for a gain of only 8 lb. of nitrogen per acre per year. Jones [1942], however, showed that continued growth of *Glycine javanica* increased soil nitrogen by 31 per cent during a period of nine years. Jenny *et al.* [1948-1950] observed that, under identical climatic conditions the tropical soils of the Central and South America, with a high proportion of legumes in their native vegetation, possessed several times more nitrogen and organic matter than the corresponding soils in North America.

The authors also observed occasional increases in soil nitrogen when some wild legumes were grown in pots for some time [Sen and Paul, 1957]. It was not known if similar increases in nitrogen also occurred under field conditions. The present work deals with the observations on changes in nitrogen and organic matter contents in soils during growth of some common wild legumes in Delhi soil under field conditions for two to three years.

MATERIAL AND METHODS

Wild legumes: The following wild legumes were studied: (1) *Alysicarpus rugosus* (2) *Cassia occidentalis*, (3) *Clitoria ternata*, (4) *Crotalaria mucronata*, (5) *Desmodium purpureum*, (6) *Dolichos lablab*, (7) *Stizolobium deeringianum*, (8) *Phaseolus lathyroides*, (9) *Stizolobium cochinchinensis* and (10) *Tephrosia purpurea*.

The wild legumes were sown in plots measuring $5{\cdot}5 \times 4{\cdot}8$ feet, there being three such plots for each legume with a plot of similar size without any legume to serve as control. Before the experiment was started, composite samples of soil up to three feet depth from area under each legume including the controls were collected and analysed for nitrogen and carbon contents. As the growth habits of the legumes were not found to be similar, some like *Stizolobium deeringianum* occupying a very large space in the field within a short time, while others like *Desmodium purpureum* occupying comparatively much less area, the plants were grown in such a way as to cover the entire

plots within a month of its growth. Though the number of the latter plants were much larger than those of the former, fairly comparative results were expected this way. The plants were allowed to grow for three years with the exception of *Clitoria ternata* and *Tephrosia purpurea* which were grown only for two years. At the end of the period, samples of soil from each plot were taken up to a depth of three feet and nitrogen and organic carbon contents of the soils were determined.

Apparent densities of the soils of the plots were determined up to three feet from the weight of one foot long soil cylinders of uniform volume obtained with the help of a steel sampling tube. The soil cylinders were dried in the oven before determination of their weights. Apparent densities of the soils of cropped and control plots were averages for each depth for calculation of nitrogen and organic carbon in lbs. per acre.

Methods: The nitrogen contents of the soils were determined by the Kjeldahl method of digestion using salicylic acid and thiosulphate, and the carbon contents by the rapid chromic acid titration method of Walkley and Black [1934].

RESULTS

Nitrogen contents of the soil under the different summer wild legumes are given in Table I.

TABLE I. NITROGEN CONTENTS OF THE SOIL UNDER WILD SUMMER LEGUMES
(the results are expressed on moisture free basis)

Depth in feet	Nitrogen in soil without legume				Nitrogen in soil under legume	
	Before 3 years		After 3 years		After 3 years	
	per cent	lb./acre	per cent	lb./acre	per cent	lb./acre
			Aliscicarpous rugosus			
1	0·035	1,277	0·035	1,277	0·0427±0·0012	1,360
2	0·022	773	0·022	773	0·0227±0·0027	766
3	0·017	616	0·018	652	0·0173±0·0023	626
		2,666		2,702		2,752
			Cassia occidentalis			
1	0·037	1,350	0·041	1,496	0·0483±0·0029	1,538
2	0·022	773	0·021	737	0·0230±0·0002	776
3	0·016	579	0·014	507	0·0160±0·0010	579
		2,702		2,740		2,893
			Clitoria ternata			
1	0·040	1,460	0·039	1,423	0·0477±0·0010	1,519
2	0·017	597	0·017	597	0·0210±0·0012	709
3	0·015	543	0·015	543	0·0180±0·0025	652
		2,600		2,563		2,880

TABLE I NITROGEN CONTENTS OF SOILS UNDER WILD SUMMER LEGUMES —(*Contd.*)

Depth in feet	Nitrogen in soil without legume				Nitrogen in soil under legume	
	Before 3 years		After 3 years		After 3 years	
	per cent	lb./acre	per cent	lb./acre	per cent	lb./acre
			Crotalaria mucronata			
1	0·033	1,204	0·035	1,277	0·0393±0·0027	1,251
2	0·021	737	0·019	667	0·0210±0·0011	709
3	0·018	652	0·015	543	0·0170±0·0006	616
		2,593		2,487		2,576
			Desmodium purpureum			
1	0·037	1,350	0·036	1,313	0·0390±0·0015	1,243
2	0·023	808	0·018	652	0·0237±0·0012	800
3	0·015	543	0·015	543	0·0163±0·0018	590
		2,701		2,488		2,633
			Dolichos lablab			
1	0·033	1,204	0·034	1,241	0·0430±0·0025	1,370
2	0·021	737	0·021	737	0·0217±0·0009	733
3	0·017	616	0·014	507	0·0163±0·0007	605
		2,557		2,485		2,708
			Stizolobium deeringianum			
1	0·037	1,350	0·039	1,423	0·0510±0·0035	1,625
2	0·023	805	0·021	735	0·0293±0·0028	989
3	0·017	616	0·015	543	0·0167±0·0007	605
		2,771		2,701		3,319
			Phaseolus lathyroides			
1	0·037	1,350	0·037	1,350	0·0423±0·0023	1,347
2	0·021	737	0·020	702	0·0230±0·0011	776
3	0·016	579	0·015	543	0·0160±0·0006	579
		2,666		2,595		2,702
			Stizolobium cochinchinensis			
1	0·035	1,277	0·036	1,313	0·0460±0·0049	1,465
2	0·024	841	0·019	661	0·0220±0·0006	744
3	0·018	652	0·016	579	0·0147±0·0008	532
		2,770		2,558		2,741
			*Tephrosia purpurea**			
1	0·037	1,350	0·037	1,350	0·0420±0·0026	1,338
2	0·020	702	0·020	702	0·0207±0·0007	699
3	0·015	543	0·015	543	0·0150±0·0006	543
		2,595		2,595		2,500

* grown only for two years

The total nitrogen and carbon contained in the soils have been calculated from the percentage of nitrogen in the soil and the average apparent densities of the soil at different depths which are given below:

Depth in feet	*Uncropped*	*Cropped*
1	1·34	1·17
2	1·28	1·24
3	1·33	1·33

Walkley and black carbon values of the soils under the different summer wild legumes are given in Table II.

TABLE II. THE CARBON CONTENT OF THE SOILS UNDER SUMMER WILD LEGUMES (the results are expressed on moisture free basis)

Depth in feet	Carbon in soil without legume				Carbon in soil under legume	
	Before 3 years		After 3 years		After 3 years	
	per cent	lb./acre	Per cent	lb./acre	per cent	lb./acre
			*Alysicarpus rugosus**			
1	0·176	6,420	0·176	5,910	0·2710±0·0130	7,389
2			0·092	2,739	0·0903±0·0089	3,342
3			0·060	2,354	0·0790±0·0206	2,643
				11,003		13,374
			Cassia occidentalis			
1	0·188	6,858	0·263	9,594	0·2700±0·0300	8,600
2			0·092	3,231	0·1113±0·0155	3,757
3	0·075	2,716	0·055	1,992	0·0633±0·0089	2,292
				14,817		14,649
			*Clitoria ternata**			
1	0·200	7,296	0·188	6,858	0·2117±0·0073	6,743
2	0·092	3,231	0·083	2,915	0·0830±0·0017	2,802
3	0·070	2,535	0·066	2,390	0·0667±0·0029	2,415
		13,062		12,163		11,960
			Crotalaria mucronata			
1	0·176	6,440	0·162	5,910	0·2320±0·0112	7,389
2	0·100	3,512	0·078	2,739	0·0990±0·0109	3,342
3	0·090	3,259	0·065	2,354	0·0650±0·0036	2,643
		13,211		11,003		13,374

*Grown for two years.

TABLE II. THE CARBON CONTENTS OF SOIL UNDER WILD SUMMER LEGUMES—(*Contd.*)

Depth in feet	Carbon in soil without legume				Carbon in soil under legume	
	Before 3 years		After 3 years		After 3 years	
	per cent	lb./acre	per cent	lb./acre	per cent	lb./acre
			Desmodium purpureum			
1	0·200	7,296	0·188	6,858	0·2137±0·0052	6,806
2	0·100	3,512	0·120	4,214	0·0967±0·0033	3,265
3	0·060	2,173	0·050	1,811	0·0667±0·0067	2,415
		12,981		12,883		12,486
			Dolichos lablab			
1	0·176	6,420	0·180	6,566	0·2337±0·0222	7,443
2	0·092	3,231	0·100	3,512	0·1033±0·0033	3,487
3	0·070	2,535	0·060	2,173	0·0687±0·0059	2,488
		12,186		12,251		13,418
			Stizolobium deeringianum			
1	0·207	7,551	0·246	8,974	0·2933±0.0066	9,342
2	0·117	4,109	0·100	3,512	0·1460±0·0210	4,929
3	0·080	2,897	0·055	1,992	0·0700±0·0058	2,535
		14,557		14,478		16,806
			Phaseolus lathyroides			
1	0·200	7,296	0·256	9,339	0·2537±0·0136	8,080
2	0·133	4,671	0·100	3,512	0·1150±0·0077	4,082
3	0·090	3,259	0·108	3,911	0·0767 0·0017	2,777
		15,226		16,762		14,939
			Stizolobium cochinchinensis			
1	0·200	7,296	0·213	7,770	0·2750±0·0304	8,759
2	0·100	3,512	0·092	3,231	0·0980±0·0123	3,308
3	0·090	3,259	0·050	1,811	0·0540±0·0076	1,955
		14,067		12,812		14,022
			*Tephrosia purpurea**			
1	0·200	7,296	0·255	9,302	0·2637±0·0138	8,399
2			0·090	3,161	0·0987±0·0035	3,332
3			0·060	2,173	0·0673±0·0062	2,437
		†		14,636		14,168

†not available; * grown for two years

DISCUSSION

The data in Table I indicate that the percentage of nitrogen in the surface soils of the fields under the legumes has increased and that there have been increases in the percentages of nitrogen in the soil at other depths also. The increases have been maximum in the case of *Stizolobium deeringianum* and minimum in the case of *Desmodium purpureum*. The percentages, however, do not reveal increase in the nitrogen content of the soil because of the difference in the apparent densities of soil with and without vegetation. It will be observed that apparent density of the soils is largely affected as a result of the growth of the legume, only at the surface. If the total amount of nitrogen contained at the surface one foot depth is considered (Table I), it will be observed that there is no gain in nitrogen of the surface soil under *Desmodium purpureum*, *Phaseolus lathyroides* and *Tephrosia purpurea*, and to a certain extent under *Crotalaria mucronata* If the amounts of nitrogen contained up to three feet depth of the soil under different legumes are considered, it will be seen that definite gains in nitrogen have occurred in the case of these legumes: *Alysicarpus rugosus*, *Cassia occidentalis*, *Clitoria ternata*, *Dolichos lablab*, *Stizolobium deeringianum* and *Phaseolus lathyroides*. On the basis of the amount of nitrogen contained in the surface samples of the soils, it is also clearly seen that *Stizolobium deeringianum* may cause increase in soil nitrogen by approximately 70 lb. of nitrogen per acre per year while the minimum is contributed by *Cassia occidentalis* which amounts to about 14 lb. per acre per year. The tendency remains the same even if the nitrogen contained in the soil up to three feet depth is compared in the two cases.

The data in Table II show that there is increase in the percentage of organic carbon in the surface soil as a result of the growth of the legumes. The increase in organic matter in the soil under the legumes is, however, not real particularly in the case of the legumes *Cassia occidentalis*, *Clitoria ternata*, *Desmodium purpureum*, *Phaseolus lathyroides* and *Tephrosia purpurea* (Table II). In the case of the other legumes, there is substantial increase in organic carbon, *Stizolobium deeringianum* contributing about 123 lb., and *Alysicarpus rugosus* and *Crotalaria mucronata* about 500 lb. of organic carbon per acre per year. There have been losses and gains of organic matter from soil under legumes at lower depths and if the total organic carbon contained in the three feet deep soil under different legumes are compared, *Alysicarpus rugosus* and *Crotalaria mucronata* are seen to contribute each 263 lb. of organic carbon per year per acre foot of the soil. *Stizolobium cochinchinensis* contributes only 134 lb. of organic carbon per acre per year. *Stizolobium deeringianum* is observed to contribute on average, 258 lb. of organic carbon per year per acre foot of the soil.

SUMMARY

The effects of growth of the wild legumes can, therefore, be summarised as follows: The legumes *Desmodium purpureum* and *Tephrosia purpurea* do not appear to increase the nitrogen or organic matter content of the soil. Soil under *Crotalaria mucronata* and *Stizolobium cochinchinensis* increases in organic matter content but there is little increase in nitrogen, the Crotolaria adding more organic matter than the Stizolobium. The legumes *Cassia occidentalis*, *Clitoria ternata* and *Phaseolus lathyroides*

increase the nitrogen content of the soil but there is little improvement in the organic matter content of the soil, the Clitoria contributing the largest amount of nitrogen. The legumes *Dolichos lablab* and *Stizolobium deeringianum* contribute both organic matter and nitrogen to the soil, the *Stizolobium* contributing more of them than the *Dolichos*.

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ISOLATION OF A VITAMIN-K-ACTIVITY COMPOUND FROM THE LEAVES OF *LAWSONIA SP.*

CHEMICAL COMPOSITION OF THE AIR-DRIED LEAVES

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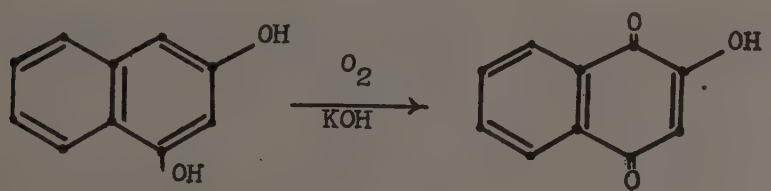
Lawsonia inermis and *Lawsonia spinosa* are shrubs widely cultivated in Egypt. Natives use the dried and finely powdered leaves in staining their hands and feet and in dyeing hair and cotton. In view of the fact that large tracts of land in Egypt are set aside for the growing of this shrub, besides the importance of its dried leaves as a hair dye and as a medicine, a brief survey of the isolation, chemical properties and analysis of the major constituents of the leaves is described.

Tommasi [1920], Lal and Dutt [1934], Condelli [1934] and Oesterle [1923] were the first who tried to analyse and isolate the constituents of the dried leaves. They gave unreliable results about some of the constituents of the leaves. The samples used by most of them are of unknown origin. Lal and Dutt [1933] used the leaves of the Indian shrubs but no quantitative data were mentioned.

LAWSONE

Separation, Chemical Properties and Synthesis

A pigment Lawsone ($C_{10}H_6O_3$), yellow crystals m.p. 193-195°, occurs in the leaves to an extent of 1 per cent from which it is extracted either by aqueous sodium carbonate or by benzene light petrol (b.p. 70-80°). It forms a mono-acetyl derivative m.p. 128°; a hydrazone m.p. 229°. With 2:4-dinitrophenyl hydrazine, a bright red crystalline dinitrophenyl hydrazone m.p. 225°, is formed. Aqueous solutions of the pigment are of an orange colour and they show a greenish fluorescence in the ultra-violet light. The pigment is identical with 2-hydroxy-1:4-naphthoquinone. It can be easily synthesised by the method of Latif and Soliman (1944) according to the following scheme:



1:3—dihydroxy naphthalene

Lawsone
2-Hydroxy-1:4—naphthoquinone

(b) *Vitamin K Activity*

The fact stated by McKee *et al.* [1939] that Vitamin K possess naphthoquinone skeleton leads the author to suggest that Lawsone may have some Vitamin K activity. Fieser *et al.* [1941], Dam *et al.* [1940] and Almquist and Klose [1939] stated that 2-methyl-1:4-naphthoquinone (menadione) is a highly potent Vitamin K activity compound and is active as Vitamin K itself. The introduction of a hydroxyl group in the 3-position reduces its activity. Thus, Phthiocol (2-methyl-3-hydroxy-1:4-naphthoquinone) has good antihemorrhagic activity. Lawsone (2-hydroxy-1:4-naphthoquinone) found to be a weakly or feebly active compound but still retain some activity. From the above finding, Lawsone can be used, below its lethal dose (50 mg. per Kg. of body weight), as a Vitamin K substitute specially for poultry.

Carbohydrates Present in the Dried Leaves

The finely powdered dried leaves is extracted first with absolute alcohol and then with petroleum-ether (b.p. 60-70°). The residue is treated with hot water and filtered. The aqueous extract, upon evaporation on a water-bath, yielded a red-brown viscous mass. By applying paper chromatography, sugars were separated. The chromatogram was run with a mixture of n-butanolethanol-water mixture. Spots of sucrose, galactose, glucose (or fructose) and xylose were made visible by spraying the chromatogram with alcoholic solution of aniline oxalate. If the chromatogram was sprayed, according to Bradfield [1950] and Hackman [1952], with an alcoholic solution of bromocresol purple containing solutions of boric acid and borax, mannitol appeared as yellow spot on a blue background.

The author was unable to detect starch when he used 1 per cent alcoholic iodine solution as a developing agent [Hattori, 1951].

Acidic Constituent of the Leaves

Dried and finely powdered leaves were extracted in a soxhlet apparatus with ether. The ethereal extract washed several times with sodium bicarbonate solution. On acidification, the bicarbonate solution gave a semi-solid brownish material. It was filtered and then crystallised from water (animal charcoal was used as a decolourising agent). It formed silky needles (m.p. 253-254°; decomp.). On heating above its melting point, carbon dioxide was liberated and pyrogallol was formed. The melting point of this acidic material showed no depression when admixed with an authentic sample of gallic acid. Ten grams of the dried leaves gave 0·5-0·69 gm. of gallic acid. It can be used in the manufacture of the ordinary blue-black ink.

ANALYSIS

Different samples of air-dried leaves are brought from Sharkia and from upper Egypt. There is slight difference in the analyses of the different samples. Aqueous extracts of Henna leaves have a slight acid reaction; the *p*H lies between 5·3-5·7. The

following results are the average chemical analysis of different air dried Henna leaf:

	Per cent		Per cent
Moisture	8-9·5	Crude fibre	6· 5- 7·0
Total ash	7·2-7·8	Starch	absent
Nitrogen	1·3-1·6	Sugars, as glucose	11-11·5
Cold-water extract	36·5	Tannin	absent
Alcohol extract	28·5-30·7	Gallic acid	5· 0- 0·6
Benzene exract	6·8- 7·3	Hydroxynaphthaquinone	1· 0
Petroleum extract	9·1-10		

It must be noted here that extracts from the leaves will precipitate gelatin and give tannin-like colours with iron and copper salts, but the extracts show no tannin reaction with cinchonine or quinine and above all they do not tan.

The dark orange-red tint produced on staining the hands with powdered leaves does not agree with the amount of Lawsone separated by the methods cited before. For this fact, the author suggests that besides the naphthaquinone-pigment detected, a compound (or compounds)—probably a meta-dihydroxy-naphthalene—is present. The latter compound stains the hand orange-red, and cannot be separated by the procedures stated as it is easily oxidised in alkaline medium by oxygen of the air to Lawsone [Latif and Soliman, 1944].

By using the paper chromatography technique, previously adopted by Sporston and Bassett [1954], for the separation of substituted naphthaquinones and by Evans [1949] for the identification of phenols and naphthols, the author detected 1:3-dihydroxy-naphthalene. An alcoholic extract of the powdered dried leaves is spotted on a strip of Whatman No. 1 filter paper. A developing solvent of the following composition is used throughout—n-amyl alcohol: pyridine: saturated aqueous sodium chloride solution 3:2:1·5. On spraying the chromatogram with a 5 per cent aqueous solution of potassium hydroxide, orange and light red (rose) spots are produced. They are identical with those achieved by authentic samples of 2-hydroxy-1:4-naphthaquinone and 1:3-dihydroxy-naphthalene respectively.

SUMMARY

2Hydroxy-1:4-naphthaquinone (Lawsone), gallic acid and mannitol were separated from the dried leaves of Henna.

By using paper chromatography technique, sucrose, galactose, glucose (or fructose), xylose and 1:3-dihydroxy naphthalene were detected in the Henna leaf extract.

Lawsone has Vitamin K activity and can be used as a Vitamin K substitute for poultry.

Complete analysis of the different air-dried Henna leaves was given.

Starch and Tannin cannot be detected.

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NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES

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Most of the fruits and vegetables in common use in India have been analysed and the data reported in *Health Bulletin* No. 23 Aykroyd *et al.*, [1956]. Besides these, there is quite a large number of fruits and vegetables which are essentially seasonal and the consumption of which is confined only to certain regions in the country. Information on the nutritive value of these is often needed but not available.

Among common fruits, like the banana, there are several varieties, and data on the nutrient content of different varieties are not often available. Such information may be of much help at times.

The present report deals with the information obtained on the nutritive value of some Indian fruits and vegetables which were examined with the objectives mentioned above.

MATERIAL AND METHODS

Samples: The fruits and vegetables were collected with the cooperation of the officers of the Departments of Public Health, Agriculture and Nutrition in the various States. Attempts were made to obtain the specimens in as fresh a state as possible and to analyse them immediately. Details regarding the source, botanical name, etc., of the samples are given in Table I.

TABLE I. DETAILS REGARDING THE SAMPLES INVESTIGATED

Name of fruit or vegetable	Botanical name	Source of supply	Remarks
1	2	3	4
		FRUITS	
Apricots fresh. Fragmore early variety	*Prunus armeniaca*	Pomological Station, Coonoor	Grown in Kashmir and other hilly tracts of India
Apricots—dried	–do–	Bought from several shops at Coonoor	
Bael	*Aegelē marmelos*	Superintendent, Fruit Research Station, Anantharajupet, Cuddappah and also from West Bengal	Season—April-June. Used in squashes, cold drinks, especially in Bengal and U.P.; also to adulterate opium. Grown wild in plains of South India, especially in Shiva temples
Bamboo fruits	*Bambusa arundinacea*	District Agricultural Officer, Lushai Hills, Assam	Fruits from trees flowering once in 49-50 years. Rodents are reported to proliferate enormously by eating these

TABLE I. DETAILS REGARDING THE SAMPLES INVESTIGATED (*Contd.*)

1	2	3	4
Banana-Krishnavazhai	*Musa paradisiaca L.*	Central Banana Research Station, Aduthurai, Tanjore Dt.	Fairly thick rinded fruits. Popular in Lower Pulneys
Banana—Laden	*Musa paradisiaca L.*	Kallar Fruit Station	Fruits with thick rind. Popular in Mettupalayam and Kallar
Banana—Pachanadan	*Musa paradisiaca L.*	Central Banana Research Station, Aduthurai, Tanjore Dt.	Fairly thick green rinded fruits. Popular in Coimbatore and other places in South India
Banana—Raja Vazhai	*Musa sapientum L.*	–do–	
Banana—Rastali	*Musa sapidisiaca L.*	Kallar Fruit Station	Popular in South India. Thin rind
Banana—Then Kunnan	*Musa paradisiaca L.*	Central Banana Research Station, Aduthurai, Tanjore Dt.	Popular in Malabar
Banana—Thenkadali	–do–	–do–	Syn. Chakkarkeli, popular in Circars
Banana—Vellakadali	*Musa paradisiaca*	–do–	Popular in Malabar
Barhar	*Artocarpus lakoocha*	Bailoor & Kawdoor villages near Karkal, Mangalore	Used instead of tamarind for cooking, especially in South Kanara, Kannada : *Vote huli;* Tulu: *Esalupuli*
Bilimbi	*Averrhoa bilimbi*	Kallar Fruit Station	A substitute for tamarind in South Kanara, foot of Nilgiris and plains
Black berry	*Rubus frucicocus*	Pomological Station, Coonoor	Season: October, December, May, June. Used in making jams and as dessert fruits. Grown in Nilgiris and Kashmir
Cherimoyer	*Anona cherimolia*	–do–	Grown in hilly tracts about 4,000 feet above Mean Sea Level. Season: November to January. The white soft pulp is edible.
Coconut water—5 month old nuts	*Cocos nucifera*	Superintendent, Coconut Research Station, Nileshwar	12 bunches in 12 selected trees of the West Coast tall type were reserved and one nut from each bunch plucked every month. Six nuts constituted one sample and the other six a second sample. The same bunches supplied nuts at different stages of maturity month after month.
Coconut water—6-month old nuts	*Cocos nucifera*	–do–	The yield of juice per nut decreased progressively from ca. 220 ml. in the 5th month to ca. 60 ml. in the 12th month. There was practically no kernel formed in the 5th month and it gradually increased to a thickness of ca. 14 mm. in the 12th month. The yield of milk was ca. 30 per cent of the kernel weight.
Coconut water—8-month old nuts	–do–	–do–	
Coconut water—10-month old nuts	–do–	–do–	
Coconut water—12-month old nuts	–do–	–do–	
Coconut milk from 10-month old nuts	–do–	–do–	
Coconut milk from 12-month old nuts	–do–	–do–	

TABLE I. DETAILS REGARDING THE SAMPLES INVESTIGATED (*Contd.*)

1	2	3	4
Currants—black		Bought from several shops at Coonoor	
Dates—dried	*Phoenix dactylifera*	–do–	Fresh fruits are harvested in May-July at Saharanpur
Guava—Japanese		Mrs. DeJong, Woodford, Coonoor	
Langsat	*Lansium domesticum*	Burliar Fruit Station	The white pulp inside is used for preparing squashes
Lichi	*Lichi chinensis* or *Nephelium lichi*	Kallar and Burliar Fruit Station	Grown in foot of Nilgiris, Bengal, Darjeeling and the Punjab. Eaten as such
Mulberry—English black	*Morus nigra*	Pomological Station, Coonoor	Used as a dessert fruit and in making jams
Mulberry—M.R.2	*Morus latifolia*	Government Silk Farm, Coonoor	Fruits eaten as such
Passion fruit—Giant	*Passiflora quadrangularis*	Burliar Fruit Station and Wynaad Fruit Station	Grown in the foot of Nilgiris and Kodai Hills. The fruit is consumed as such and also used in making jams, jellies and squashes
Passion fruit—yellow	*Passiflora edulis*	Kallar Fruit Station	Season: August to September. Available in Nilgiris. The viscous pulp without the seeds is consumed. The fruit yields about 20 per cent of its weight as juice
Pears—Chinese	*Pyrus chinensis*	Pomological Station, Coonoor	Grown in Nilgiris, Yercaud and Kodai Hills. Eaten as such
Pears—Kieffer	*Pyrus communis*	–do–	–do–
Persimmon	*Diospyros kaki*	Pomological Station, Coonoor	Grown in Nilgiris and used as dessert fruit
Plums—Shiro	*Prunus salicina*	–do–	Found in Nilgiris, Darjeeling, Kashmir, Kodai Hills and Yercaud. Eaten as such
Plums—Gaviota	–do–	–do–	–do–
Plums—Hale	–do–	–do–	–do– Used in jams also
Plums—Rubio	–do–	–do–	–do– Used in jams also
Plums—Satsuma	–do–	–do–	–do–
Prunes	–do–	Bought from several shops at Coonoor	Mostly imported from abroad
Raisins—cheap		–do–	Known also as Sultanas, said to be obtained from Bombay. Cost about Rs. 1/8/- per lb.

TABLE I. DETAILS REGARDING THE SAMPLES INVESTIGATED (*Contd.*)

1	2	3	4
Raisins—costly		–do–	Said to be imported from abroad. Cost about Rs. 2/8/- per lb.
Raisins with seeds		–do–	Said to be obtained from Bombay. Cost about Rs. 2/8/- per lb.
Sapotas—cricket ball variety	*Achras zapota*	Kallar Fruit Station	Consumed as such. Season: July to September
Tuki	*Disopyros melanoxylon*	District Forest Officer, Cuddappah	Grown wild in Kashmir, Punjab, Nilgiris and hilly tracts of Andhra. The yellow pulp inside is edible
		VEGETABLES	
Amaranth seeds (*Arakkeerai*)	*Amaranthus tristis*	Soundarya Nursery, Madras	
Amaranth seeds (*Sirukeerai*)	*Amaranthus polygonoides*	Soundarya Nursery, Madras and Raja Farm and Nursery, Madras	
Amaranth seeds (*Thandu keerai*)	*Amaranthus gangeticus*	Soundarya Nursery, Madras	
Banana rhizome	*Musa paradisiaca* L.	Kallar Fruit Station	Laden variety
Beans, runner or scarlet		Pomological Station, Coonoor	Cultivated by the hill tribes, especially by the Badagas of Nilgiris. The consumption of the seeds of the mature bean is more popular
Beet greens	*Beta vulgaris*	–do–	
Canna—edible	*Canna edulis*	Horticulturist, Indian Institute of Science, Bangalore	Grown below 3,000 feet mean sea level in Wynaad and Bangalore
Chekkur manis	*Sauropus androgynans*	Principal, Agricultural College, Coimbatore and Sri N. Raghavan. Cannanore	Said to be recently introduced in India from Borneo
Daincha seeds		Superintendent, Central Farm, Coimbatore	Grown in alkaline soils of Ramanathapuram District and all over India
Garden Sorrel—sepals		Fruit Research Station, Anantharajupet, Cuddappah	Available in the month of December. The sepals on the fruit are consumed in the form of pickles and jellies
Giant capsicum	*Capsicum annum*	Pomological Station, Coonoor	Used as a vegetable and condiment. Grown all over the South in plains especially Tanjore District
Knol-khol greens	*Brassica caulorapa*	–do–	

TABLE I. DETAILS REGARDING SAMPLES INVESTIGATED (*Concld.*)

1	2	3	4
Mahua flowers	Mixture of *Bassia latifolia* and *Bassia longifolia*	Banana Research Officer, Aduthurai, Tanjore Dt.	Longifolia is natural to South India and is found in Mysore, Malabar, the Annamalais and Circars. Common in dry forests at lower elevations. Flowers eaten either raw or as sweet meats or baked into cakes. Flowers afford drink and food during March to September. The fermented flowers can be distilled to yield a liquor consumed by people in Central India. *Bassia latifolia* Roxb. is the variety popular in North India
Mango ginger	*Curcuma amada*	Assistant, Paddy Research Station, Pattambi	Found in West Coast. Used in pickles
Mango kernel (Neelam)		Bought from various shops in Coonoor	The kernel is dried and the powder obtained is used in some parts of India (Bihar) as *atta*. The yield of the seed kernel is about 7 per cent of the weight of the fruit
Mango kernel (Totapuri or Bangalore)		–do–	–do–
Mushrooms—paddy straw	*Valvaria diplapia*	Government Mycologist, Coimbatore	Cultivated type, edible
Pumpkin seeds	*Cucurbita maxima*	Bought from several shops at Coonoor	Consumed as such or after frying in ghee or oil in South Indian houses
Table radish, bulb	*Raphanus sativus*	Raj Bhavan Garden, Ootacamund	It is often used as a raw salad material
Table radish, leaves	–do–	–do–	–do–
		SEE WEEDS	
Gracilaria (fresh and dry)	*Gracilaria lichinoides*	Central Marine Fisheries Station, Mandapam	Used like sago by the people of Ramnad District
Hypnea (fresh and dry)	*Hypnea musciformis*	–do–	
Ulva (fresh and dry)	*Ulva lactuca*	–do–	
Sunflower seeds	*Helianthus annuus*	Oilseeds Specialist, Agricultural Research Institute, Coimbatore	
Sweet potato vine—tender leaves	*Ipomoea batatas*	Superintendent, Central Farm, Coimbatore	
Turnip greens	*Brassica rapa*	Pomological Station, Coonoor	
Wild yam	*Dioscorea versicolor*	Sent by Dr. Kaviraj Pratap Sinha, Banaras	Said to be useful in tuberculosis

Sampling and analysis: The material was cleaned free from all extraneous matter. Where necessary, small quantities of water were used to wash the samples keeping the leaching effects, if any, at a minimum and then wiped dry. A representative sample was prepared according to recognized statistical considerations like quartering or random sampling etc. depending upon the size, nature and availability of the material. At least two lots of each fruit or vegetable were sampled and analysed for each nutrient in duplicate. Stainless steel plates, knives etc. were used in handling the samples during analysis.

A portion of the cleaned material was used for estimating the percentage of edible matter. The edible matter was then analysed for the several constituents as detailed below.

Moisture, protein, fat (ether extractives), fibre and mineral matter were determined by the standard methods described in A.O.A.C. [1955]. Carbohydrates were determined as the difference between 100 and the sum of the above five constituents. Calories were calculated by using the factors, 4, 4 and 9 for protein, carbohydrate and fat respectively.

The mineral matter was dissolved in hydrochloric acid and solution prepared according to the procedure outlined by McCance *et al.* [1936]. Aliquots of the solution were used to estimate calcium, phosphorus and iron. Calcium was determined as the oxalate, phosphorus colorimetrically as the blue molybdate complex, and iron colorimetrically as the thiocyanate by the usual procedures.

Carotene was extracted from the samples with alcohol and subsequently with low boiling petroleum ether (40°C-60°C.). The interfering colour was removed with calcium carbonate and the colour due to carotene was read at 460 mμ in a colorimeter and compared with a standard curve prepared for pure carotene. One International Unit of Vitamin A was assumed to be equal to 0·6 micrograms of carotene and the results expressed in terms of I.U. Vitamin A value.

For the B complex group of vitamins, the finely divided sample was hydrolysed with taka-diastase and papain in acetate buffer to release the bound forms; aliquots of the hydrolysate were used for estimating thiamine. riboflavin and nicotinic acid [Association of Vitamin Chemists, 1951]. Thiamine was estimated fluorometrically after oxidation to thiochrome [Swaminathan, 1946] and riboflavin by employing the selective destruction with hydrosulphite [Gyorgy, 1950]. Nicotinic acid was estimated colorimetrically by the aniline cyanogen bromide procedure [Swaminathan, 1944].

Ascorbic acid was determined by visual titration with 2:6 dichlorophenol indophenol. Whenever the samples gave highly coloured extracts the total ascorbic acid was estimated by the colorimetric 2:4 dinitrophenylhydrazine procedure of Roe and Kuether [Gyorgy, 1950].

RESULTS AND DISCUSSION

Fortysix fruits and 30 vegetables were investigated and the results are presented in Table II.

Eight varieties of banana, five of plum, three of raisin and two of pear were examined. Variety did not appear to exert any striking influence on the nutrient composition of the fruits.

TABLE II. NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES

(Values per 100 gm. of edible matter)

Name of fruit	Edible matter (%)	Moisture (%)	Protein (%)	Fat (ether extractives) (%)	Mineral matter (%)	Fibre (%)	Carbohydrate (%)	Calcium (Ca) (%)	Phosphorus (P) (%)	Iron (Fe) (mg.%)	Calorific value (per 100 gm.)	Carotene (International Vitamin A Units per 100 gm.)	Vitamin B_1 (μg. per 100 gm.)	Nicotinic acid (mg. per 100 gm.)	Riboflavin μg. per 100 gm.)	Vitamin C (mg. per 100 gm.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FRUITS																
Apricots (fresh)*	85	83·6	0·8	0·2	0·7	1·0	13·6	0·02	0·02	2·1	60	5,635	48	0·3	209	4
Apricots (dried)	93	19·4	1·6	0·7	2·8	2·1	73·3	0·11	0·07	4·6	305	98	217	2·3	..	2
Bael	65	64·2	1·3	0·2	1·5	2·2	30.6	0·09	0·05	0·3	129	186	126	0·9	1191	15
Bamboo*	..	56·3	3·9	0·1	1·6	3·9	34·2	0·01	0·11	1·5	174	19	92	..	94	1
Banana (Krishna)	73	64·8	1·6	0·5	0·9	0·7	31·4	0·02	0.04	0·6	136	223	20	0·5	47	7
Banana (Laden)	68	68·0	1·0	0·2	0·9	0·4	29·5	0·01	0·03	0·6	124	28	31	..	31	6
Banana (Pachanadan)	72	66·4	1·5	0·2	0·8	0·2	30·9	0·02	0·04	0·7	132	248	27	0·5	55	6
Banana (Raja)	64	66·0	1·2	0·2	0·7	0·5	31·5	0·02	0·03	0·6	132	68	34	0·5	71	11
Banana (Rasthali)	83	74·4	1·1	0·2	0·8	0·3	23·2	0·01	0·03	0·4	99	8	43	..	21	6
Banana (Thenkadali)	66	67·2	1·5	0·2	1·0	0·4	29·6	0·02	0·04	0.8	127	470	26	0·6	62	5
Banana (Thenkunnan)	79	59·9	1·5	0·1	0·9	0·3	37·4	0·02	0·05	0·5	156	54	41	0·8	54	17
Banana (Vella kadali)	67	66·8	1·4	0·3	0·9	0·8	29·9	0·02	0·04	0·5	128	189	51	0·5	44	5
Barhar	76	82·1	0·7	1·1	0·8	2·0	13·3	0·05	0·02	0·5	66	424	24	0·3	153	135

TABLE II. NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES—*Contd.*

Name of fruit	Edible matter (%)	Moisture (%)	Protein (%)	Fat (ether extractives) (%)	Mineral matter (%)	Fibre (%)	Carbohydrate (%)	Calcium (Ca) (%)	Phosphorus (P) (%)	Iron (Fe) (mg. %)	Calorific value (per 100 gm.)	Carotene (International Vitamin A Units per 100 gm.)	Vitamin B_1 (*γ*gm. per 100 gm.)	Nicotinic acid (mg. per 100 gm.)	Riboflavin (*γ*gm. per 100 gm.)	Vitamin C (mg. per 100 gm.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bilimbi	100	95·0	0·5	0·3	0·3	1·1	2·8	0·02	0·01	1·9	15	62	118	0·9	46	8
Black berry	100	87·2	1·3	0·5	0·5	3·8	6·7	0·03	0·02	4·3	37	13	..	2·0	..	9
Cherimoyer	73	76.4	1.3	0·3	0·3	1·5	20·3	0·03	0·02	0·4	89	4	25	1·0	205	7
Coconut water (5th month)	100	93.9	0.1	<0·1	0·1	Nil	5·9	0·03	<0·01	0·2	24	Nil	7	0·1	7	2
Coconut water (6th month)	100	92.8	0.1	<0.1	0·5	Nil	6·7	0·03	0·01	0·1	27	Nil	3	0·1	3	2
Coconut water (8th month)	100	94·1	0·1	<0.1	0·4	Nil	5·2	0.02	<0·01	0·1	22	Nil	2	0·3	2	2
Coconut water (10th month)	100	94·4	0·2	<0.1	0·3	Nil	5·0	0·02	0·01	0·1	21	Nil	6	0·1	trace	2
Coconut water (12th month)	100	93.9	0·2	<0.1	0·3	Nil	5·6	0·02	0·01	0·1	24	Nil	3	<0·1	8	1
Coconut milk (10th month)	100	46·3	2·4	41·3	0·9	Nil	8·3	0·01	0·12	1·8	414	Nil	96	0·7	24	2
Coconut milk (12th month)	100	39·2	4·4	40·7	0·9	Nil	11·7	0·02	0·16	1·4	430	Nil	62	0·4	46	4
Currants	98	18·4	2·7	0·5	2·2	1·0	75·2	0·13	0·11	8·0	316	35	27	0·4	143	1
Dates (dried)	86	15·3	2·5	0·4	2·1	3·9	75·8	0·12	0·05	7·3	317	44	11	0·9	23	3
Guava, Japanese	100	80·4	0·6	0·3	0·7	6·2	11·8	0·05	0·02	0·6	52	147	9	trace	261	44
Langsat	58	86·5	0·8	0·3	0·6	2·3	9·5	0·02	0·03	0·5	44	13	89	Nil	124	1
Lichi	67	84·5	1·0	0·3	0·5	0·4	13·6	0·01	0·03	0·4	61	Nil	28	0·4	61	24
Mulberry (English black)	100	85·5	0·7	0·4	0·4	0·8	12·2	0·06	0·02	2·6	55	16	58	0·2	92	10

TABLE II. NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES—*Contd.*

Name of fruit	Edible matter (%)	Moisture (%)	Protein (%)	Fat (ether extractives) (%)	Mineral matter (%)	Fibre (%)	Carbohydrate (%)	Calcium (Ca) (%)	Phosphorus (P) (%)	Iron (Fe) (mg. %)	Calorific value (per 100 gm.)	Carotene (International Vitamin A Units per 100 gm.)	Vitamin B_1 (μgm. per 100 gm.)	Nicotinic acid (mg. per 100 gm.)	Riboflavin (μgm. per 100 gm.)	Vitamin C (mg. per 100 gm.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mulberry fruit MR_2	100	87·5	1·5	0·4	0·9	1·4	8·3	0·08	0·04	1·9	43	174	9	0·8	184	13
Passion fruit (giant)	87	91·8	0·4	0·1	0·4	0·6	6·6	0·01	0·01	0·4	29	6	103	2·4	23	64
Passion fruit juice (yellow)	100	89·0	1·2	0·2	0·7	1·2	7·7	0·01	0·03	0·7	37	3284	10	trace	23	13
Pears (Chinese)	76	84.9	0·3	0·1	0·3	3·7	10·7	0·01	0·01	0·4	45	9	6	trace	38	1
Pears (Kieffer)	82	86.3	0·2	0·2	0·2	1·4	11·7	0·01	0·01	0·4	50	9	28	trace	15	7
Persimmon	93	80·4	0·6	0.3	0·3	0·9	17.5	0·02	0.01	0.4	75	5854	25	trace	10	33
Plums (Gaviota)*	94	88·6	0·7	0·4	0·4	0·4	9·5	0·01	0·01	0·6	44	608	2	0·4	185	5
Plums (Hale)	91	85.9	0.7	0.7	0·3	0·7	11·7	0·01	0·01	0.5	56	53	..	trace	30	5
Plums (Rubio)	90	85.5	0·7	0·2	0·4	0·4	12·9	0·02	0·01	0·6	56	241	32	0·2	183	13
Plums (Shiro)	95	87·9	0·5	0.4	0·3	0·4	10·5	0·01	0·01	0·3	48	145	25	0·2	76	2
Plums (Satsuma)	..	86·5	0·7	1·0	0·5	0·3	11·2	0·01	0·01	0·3	56	42	28	0·6	69	9
Prunes	85	35·3	0·3	0·3	1·7	2·0	60·5	0·08	0·04	4·8	246	317	561	1·6	..	2
Raisins (cheap)	100	22·0	1·8	0·5	2·1	1·4	72·2	0·08	0·08	10·0	301	12	33	0·5	287	1
Raisins (costly)	100	20·2	1·6	0·3	1·8	1·1	75·0	0·08	0·08	9·2	309	Nil	111	1·3	174	3
Raisins (Seeded)	92	19·0	1·4	0·3	1·8	0·7	76·8	0·07	0·08	7·1	315	Nil	120	0·5	228	3
Sapotas	82	77·7	0·5	0·6	0·5	1·8	18·9	0·03	0·01	0·5	83	31	17	0·6	40	1
Tuki	57	70·6	0·8	0·2	0·8	0·8	26·7	0·06	0·02	0·5	112	602	6	2·3	35	1

* Figures obtained by analysis of one sample only.

TABLE II. NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES—*Contd.*

Name of Vegetable	Edible matter (%)	Moisture (%)	Protein (%)	Fat (ether extractives) (%)	Mineral matter (%)	Fibre (%)	Carbohydrate (%)	Calcium (Ca)(%)	Phosphorus (P) (%)	Iron (Fe)(mg.%)	Calorific value (per 100 gm.)	Carotene (International Vitamin A units per 100 gm.)	Vitamin B_1 (γgm. per 100 gm.)	Nicotinic acid (mg. per 100 gm.)	Riboflavin (γgm. per 100 gm.)	Vitamin C (mg. per 100 gm.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
VEGETABLES																
Amaranthus seeds (Arakkeerai)*	100	9·9	13·3	2·5	3·7	8·4	62·3	0·49	0·47	11·3	325	Nil	142	0·5	342	1
Amaranthus seeds (Sirukeerai)	100	10·1	14·4	1·0	2·8	11·4	60·1	0·58	0·35	11·7	307	Nil	33	0·8	127	1
Amaranthus seeds (Thandukkeerai)*	100	10·0	16·3	2·1	2·7	8·9	60·1	0·46	0·37	10·1	324	Nil	27	0·3	160	1
Banana rhizomes (Laden)	35	85·4	0·2	0·1	1·7	0·9	11·7	0·02	0·01	1·1	48	16	Nil	..	15	1
Beans, (runner or scarlet)	59	58·3	7·4	1·0	1·6	1·9	29·8	0·05	0·16	2·6	157	57	343	Nil	193	27
Beets green	51	86·4	3·4	0·8	2·2	0·7	6·4	0·38	0·03	16·2	46	9776	258	3·3	558	70
Canna, (edible)	73	70·8	0·8	0·5	1·1	0·5	26·5	0·03	0·03	0·8	113	3	58	1·7	57	5
Chekkur manis	100	73·6	6·8	3·2	3·4	1·4	11·6	0·57	0·20	28·0	103	9518	481	2·6	324	247
Daincha seeds	100	10·8	28·1	3·8	3·6	8·6	46·1	0·24	0·39	16·5	330	58	330	2·5	305	2
Garden sorrel, sepals	100	91·9	0·6	0·2	0·9	1·3	5·1	0·13	0·02	1·7	25	127	Nil	Nil	71	5
Giant capsicum	97	92·4	1·0	0·4	0·4	1·0	4·8	0·01	0·03	1·2	26	712	550	..	48	137
Knol khol greens	73	80·4	3·4	1·0	1·8	1·5	11·9	0·74	0.05	13·3	70	6912	250	3·0	1086	157
Mahua flower	89	18·6	4·4	0·6	2·7	1·7	72·9	0·14	0·14	15·0	314	39	32	5·2	878	7
Mango ginger	87	90·3	1·0	0·5	1·0	1·2	6·0	0·02	0·08	2·6	32	34	11	trace	26	1
Mango seed kernel (Neelam)	54	47·1	2·6	5·1	1·4	0·8	43·0	0·05	0·11	0·7	228	24	210	Nil	105	6

TABLE II. NUTRITIVE VALUE OF SOME INDIAN FRUITS AND VEGETABLES—*Contd.*

Name of vegetable	Edible matter (%)	Moisture (%)	Protein (%)	Fat (ether extractives) (%)	Mineral matter (%)	Fibre (%)	Carbohydrate (%)	Calcium (Ca) (%)	Phosphorus (P) (%)	Iron (Fe) (mg.%)	Calorific value (per 100 gm.)	Carotene (International Vitamin A units per 100 gm.)	Vitamin B_1 (μg@. per 100 gm.)	Nicotinic acid (mg. per 100 gm.)	Riboflavin (μg@. per 100 gm.)	Vitamin C (mg. per 100 gm.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mango seed kernel (Totapuri or Bangalore)	56	63·2	2·2	3·3	1·2	1·0	29·1	0·03	0·09	0·8	155	44	217	Nil	279	11
Mushroom, paddy straw	88	88·6	3·8	0·7	1·4	0·4	5·1	0·01	0·10	1·5	42	Nil	141	2·4	605	12
Pumpkin seeds	70	8·0	24·3	47·2	4·7	0·2	15·6	0·05	0·83	5·5	584	76	330	3·1	162	1
Radish, table (bulb)	100	94·9	0·5	0·1	0·7	0·6	3·3	0·02	0·02	1·0	16	8	21	1·4	27	21
Radish, table (leaves)	49	89·1	3·9	0·6	1·6	0·6	4·1	0·31	0·06	18·0	37	9576	179	5·5	352	106
*Seaweeds**																
Gracilaria (fresh)	100	90·0	0·9	0·2	5·2	0·4	3·3	0·06	0·01	5·9	19	1350	54	1·1	..	4
Gracilaria (dry powder)	100	6·3	12·5	0·8	25·4	5·4	49·7	0·89	0·11	..	246	165	Nil	Nil	..	1
Hypnea (fresh)	100	92·7	0·7	0·2	2·5	0·3	3·6	0·15	0·01	8·3	19	439	37	2·0	..	1
Hypnea (dry powder)	100	12·8	10·1	0·9	18·0	4·6	54·1	1·60	0·15	..	265	22	58	Nil	..	1
Ulva (fresh)	100	90·7	0·7	0·2	4·4	0·3	3·7	0·19	0·01	5·9	19	1010	81	2·1	..	2
Ulva (dry powder)	100	9·5	9·7	0·3	24·7	5·2	50·6	2·14	0·08	..	244	149	24	Nil	..	1
Sunflower seeds	52	5·5	19·8	52·1	3·7	1·0	17·9	0·28	0·67	5·0	620	Nil	858	5·0	315	1
Sweet potato, greens	100	80·7	4·2	0·8	2·2	2·4	10·7	0·36	0·06	10·0	67	1255	71	1·7	240	27
Turnip greens	51	81·9	4·0	1·5	2·2	1·0	9·5	0·71	0·06	28·4	68	15,665	309	5·4	572	180
Wild yam*	89	70·4	2·5	0·3	1·4	1·0	24·4	0·02	0·07	1·0	114	943	185	1·2	465	1

* Figures obtained by analysis of one sample only.

Fresh apricots and persimmon were found to be rich in carotene. The dried fruits like raisins and apricots appear to be good sources of thiamine. Barhar, a fruit used in some western Indian homes as a substitute for tarmarind, contained good amounts of Vitamin C. Hill fruits like bilimbi and black berry were in general rich in iron. It was observed that black berry contained no thiamine and an extract of the fruit inactivated any pure thiamine added to it [Belavady, 1955]. Further investigations on this aspect may be worthwhile.

The green leafy tops of the several tubers—knol-khol, turnip, radish and beetroot, which are usually thrown away are very nutritious, being rich in all the vitamins and minerals. However, some of these are rich in oxalic acid and part of the calcium may not be available. Such instances are but rare. Chekkur manis, a leafy vegetable recently introduced from Borneo appears to be uniquely rich in all the nutrients and deserves all encouragement.

Giant capsicum is rich in vitamin C and thiamine. Pumpkin seeds are fairly rich in fat (ca. 47 per cent) which appears to merit further investigation.

The seaweeds studied in the present series appeared to contain a good proportion of a setting material of the agar-agar type and their potentialities from this angle may deserve detailed investigation.

SUMMARY

Data on protein, fat, carbohydrates, minerals (Ca, P and Fe) and vitamins (A, B_1, B_2, niacin and C) of 46 fruits and 30 vegetables are presented.

The value of some hill fruits as sources of iron and of fruits like persimmon as source of carotene has been brought out in these investigations.

The leafy tops of some root vegetables are rich in nutrients and deserve to be consumed after the required processing.

Variety does not appear to influence the nutritive value of bananas, plums, pears or sultanas.

The seaweeds available on the coast of South India appear to be potential sources of a setting material of the agar-agar type.

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DESCRIPTIVE STUDIES ON BANANA

THE MONTHAN AND PEYAN GROUPS

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The *Monthan* (Syn. *Bontha*, *Bainsa*, *Bankel*, *Kanch Kela*, and *Ponthan*) is a well-known culinary variety of banana. The various types of this variety with slight variations in the size, shape and quality of fruits are under cultivation on a commercial scale in India. Apart from these types which can more or less be considered synonymous, there are certain distinct varieties exhibiting identical characters as those of *Monthan*, but differing in a few attributes, bearing different varietal names in the localities in which they are dispersed. *Peyan* is another important group of dessert bananas in South India synonymous with *Bhurkel* of Bombay. As in *Monthan*, several varieties bearing a close resemblance to each other are under cultivation. An attempt has been made in this article to record detailed descriptions of each of these varieties and to study their taxonomical status. These two groups of bananas have been considered together, because of certain unmistakable evidences of their common ancestry, which are discussed in this paper.

REVIEW OF LITERATURE

Venkataramani [1946] has recorded descriptions of some of the varieties under both these groups, but without any attempt at classification. Jacob [1952] has described 17 of the 18 varieties dealt with in this article, classifying them under three groups viz. (i) *Monthan* (ii) *Mannan* and (iii) *Peyan*. It is apparent from his description that characters such as fruit size, nature of the petiole, lamina base and the use to which the fruit is put, have played an important role in the grouping of the varieties. It is clear, however, that the ancestry of the varieties has not been taken into account in his classification. Recent trends in classification of bananas, however, lay considerable stress on the relationship between the cultivated varieties and their wild progenitors [1948].

MATERIAL AND METHODS

In the present investigation, 18 varieties of the *Monthan* and the *Peyan* groups, cultivated in the wetlands of the Central Banana Research Station, Aduthurai (Tanjore District, Madras) have been described in detail. The characters distinguishing each group have been enumerated in the following pages, followed by a list of characters which distinguish the individual varieties from the main group and between one another.

MONTHAN GROUP (Fig. 1)

Description of group characters

Plant: 220-398 cm. in height, 44-60 cm. in girth, tall or medium tall, yellowish green with dark patches near the petioles, waxy bloom abundant near the petioles and young regions.

FIG. 1. *THE MONTHAN GROUP*–1. MONTHAN, 2. NALLA BONTHA, 3. KALLU MONTHAN, 4. NEY MANNAN, 5. PEY LADAN, 6. MAYIL VAZHAI, 7. KURI BONTHA, 8. MALE BUD OF MONTHAN, 9. MALE BUD OF NEY MANNAN

Leaf: Petiole 45-65 cm. in length, 11-16 cm. in girth, well spread, clasping the pseudostem tightly, yellowish green with profuse waxy bloom, margin incurved and edges almost meeting, with bluish brown pigmentation; *lamina:* 147-230 cm. in length, 52-75 cm. in breadth, upper surface dark green, lower surface dull green and glaucous, texture very thick, mid rib yellowish green on the lower surface or flesh coloured occasionally and green on the upper surface, base unequal and auricled, apex truncate.

Inflorescence: Pendulous; peduncle glabrous with two sterile bracts coloured dark pink with green tinge, exhibiting foliage characters, bracts with fruiting flowers dull pink with profuse ashy bloom, longitudinal grooves visible only in the basal half, inner colour of bracts uniformly crimson.

Female flowers: Biseriate; *united tepal:* 4·0 to 4·5 cm. in length, 1·6 to 2·0 cm. in breadth, coloured deep pink with hyaline margin, lobes five, deep yellow; *free tepal:*

deep pink or transluscent white or light suffused pink tinge, 1·9 to 2·0 cm. in length; *staminodes:* 5, filaments 2·6 to 3·0 cm. in length, white with suffused pink tinge in the lower half; anther rudimentary; *pistil:* vary, 3-5 sided, angular, parrot green in colour; *style:* 4·0 to 4·2 cm. in length, white with pink dots; *stigma:* capitate and dirty white.

Male bud: Usually ellipsoid or ovoid, imbricate, outer colour of bracts bluish purple with profuse ashy bloom, longitudinal grooves prominent only in the basal half, inner colour of bracts uniformly crimson, bracts and male flowers deciduous.

Male flowers: Biseriate; *united tepal:* deep pink, 4·4 to 4·7 cm. in length, 1·6 to 1·8 cm. in breadth, five lobed, lobes yellow; *free tepal* deep pink, 3·1 to 3·3 cm. in length; *stamens:* five, filament 2·1 to 2·3 cm. in length, pale white with light pink tinge, anther lobes 2·3 to 2·4 cm. in length, cream coloured; *pistillode:* aborted ovary 2·8 to 3·0 cm. in length, pale white with pink blotches, conical; *style:* 4·5 to 4·6 cm. in length, thin, coloured pale white with dots; *stigma:* round, small and cream coloured. *Bunch:* peduncle glabrous, 26-31 cm. in length, 13–16 cm. in girth, dull green, fruit bearing axis 16-34 cm. in length, number of hands 5-22, wrist not prominent, bunch lax to compact; *fruits:* edible portion 9·3 to 13·5 cm. in length, 11·5 to 15·9 cm. in girth, angular and highly compressed, pedicel 2·7 cm. to 4·0 cm. in length, apex 1·8 cm. to 3·7 cm. in length, fruits green or ashy coated at maturity, on ripening dull yellow, thickness of skin on ripening 0·3 to 0·4 cm., flesh of a full yellow or white colour, insipid in taste, aborted seeds visible, fruits strongly attached to pedicel. *Suckering:* free, 6-10 in number; duration 490-520 days.

Varieties, Types and Synonyms

1. *Monthan.* Syn. *Erode Monthan, Bontha, Bainsa, Malai Monthan, Ponthan, Pacha Bontha, Sorra Monthan, Supari, Lambi, Kanch Kela, Kach Kol:* Plants 326 cm. to 356 cm. in height, 56-71 cm. in girth, mid-rib yellowish green; male bud ellipsoid, united tepal as well as free tepal deeply pigmented; bunch pendant and not compact, 20-31 lb. in weight, number of hands 6-11, fruits rather uniform, edible portion 13·5 cm. in length, 15·9 cm. in girth, fruits angular and compressed, apex 3·7 cm. in length, terete, pedicel 3·5 cm. in length, thickness of skin in fully ripened fruit 0·4 cm.; average duration 496 days.

2. *Nalla Bontha.* Syn. *Monthan, Madhuranga Bale, Bluggoe:* resembles *Monthan* except for its apex which is angular and indistinct; average duration 490 days.

3. *Sambrani Monthan.* Syn. *Chara Ponthan:* Fruits ashy-coated; in other characters resembles *Monthan;* average duration 504 days.

4. *Thella Bontha:* An ashy coated type of *Valla Bontha;* average duration 516 days.

5. *Pacha Bontha Batheesa.* Syn. *Batheesa green, Ther Vazhai:* It is a mutant type of *Monthan,* bunch compact, 45-51 lb. in weight with 251 to 332 fruits and 18 to 24 hands, fruits are not uniform being very small in the lower hands; avearge duration 451 days.

6. *Booditha Bontha Batheesa.* Syn. *Batheesa Ashy:* Resembles *Pachan Bontha Batheesa* except for its ashy bloom on the rind; average duration 519 days.

7. *Nalla Bontha Batheesa.* Syn. *Adukku Monthan:* In plant and fruit characters resembles *Nalla Bontha,* bunch pendant and compact, fruits not uniform, bunch weight 42-53 lb., number of hands 18-22; average duration 516 days.

8. *Kallu Monthan:* Plants tall, 342-398 cm. in height, 61-82 cm. in girth, mid-rib yellowish green, male bud ellipsoid, floral parts pigmented; *bunch:* pendant and fruits are held in a lax manner, bunch 14-18 lb. in weight, number of hands 5-8, number of fruits 60-78; *fruit:* resembles *Nalla Bontha* in shape but reduced in size, length of edible portion 8·5 cm., girth 10·5 cm., apex 2·2 cm. in length, pedicel 4·0 cm. in length, skin on ripening 0·3 cm. in thickness; average duration 475 days.

9. *Ney Mannan.* Syn. *Ney Vannan, Vayal Vazhai, Nanguneri Peyan, Nattu Vazhai, Chinna Monthan:* Plants 254-273 cm. in height, 51-62 cm. in girth, mid-rib on the lower surface flesh coloured, floral parts pigmented, male bud ovoid; *bunch:* pendant fruits 120-168; compact, bunch weight 21-28 lb., number of hands 6-10, number of and rather *fruits:* length of edible portion 10 cm., girth 12·1 cm., length of pedicel 3·4 cm., length of apex 1·8 cm., fruits insipid. This is primarily a cooking variety used as table fruits in certain parts of Madras State; average duration 528 days.

10. *Venneettin Mannan.* Syn. *Chara Vannan:* Fruit rind ashy-coated; in other characters resembles *Ney Mannan;* average duration 531 days.

11. *Kuri Bontha.* Syn. *Pidi Monthan*: Plant medium tall, 216-255 cm. in height, 56-61 cm. in girth, mid-rib yellowish green, floral parts including free tepal pigmented; male bud ellipsoid; *bunch:* pendant and rather compact; 7 to 17 lb. in weight, with three to six hands and 22 to 86 fruits; *fruits:* edible portion 9·6 cm. in length, 12·1 cm. in girth, apex 1·7 cm. in length, pedicel 3·1 cm. in length, inferior in dessert quality; average duration 346 days.

12. *Pey Ladan:* Plants medium tall, 272-293 cm. in height, 59-70 cm. in girth, mid-rib flesh coloured on the lower surface, free tepal transluscent white, occasionally with light suffused pink tinge, male bud ellipsoid; *bunch:* pendant and rather compact, 13-16·5 lb. in weight, 5-7 hands, number of fruits 70-84; *fruits:* edible portion 9·3 cm. in length, 12·6 cm. in girth, apex 1·3 cm. in length, indistinct and tapering, pedicel length 3·4 cm., inferior in dessert qualities, can be used for cooking; average duration 514 days.

13. *Mayil Vazhai:* In plant characters, it resembles *Pey Ladan; bunch:* pendant and rather compact, bunch weight 14-16 lb., 5-7 hands, number of fruits 60-72; *fruits:* length of edible portion 9·6 cm., girth 11·2 cm., apex 2·6 cm. in length, length of pedicel 2·7 cm., insipid; average duration 498 days.

PEYAN GROUP (Fig. 2)

Description of Group Characters

Pseudostem: 210-445 cm. in height, 56-87 cm. in girth, pale green or dark green, robust and tall, ashy bloom profuse near young regions and petioles; *leaf:* petiole 42-60 cm. in length, 11·5 to 16 cm. in girth, well spread, yellowish green or dark green, waxy bloom present in plenty, margins incurved and meeting, colour of margin browish black, leaf-sheath clasping the pseudostem tightly; *lamina:* 169-200 cm. in length, 50-62 cm. in breadth at the middle, upper surface coloured dark green, lower surface dull green and glaucous, very thick in texture, mid-rib flesh-coloured or yellowish green, upper surface yellowish green, base unequal and auricled, apex truncate.

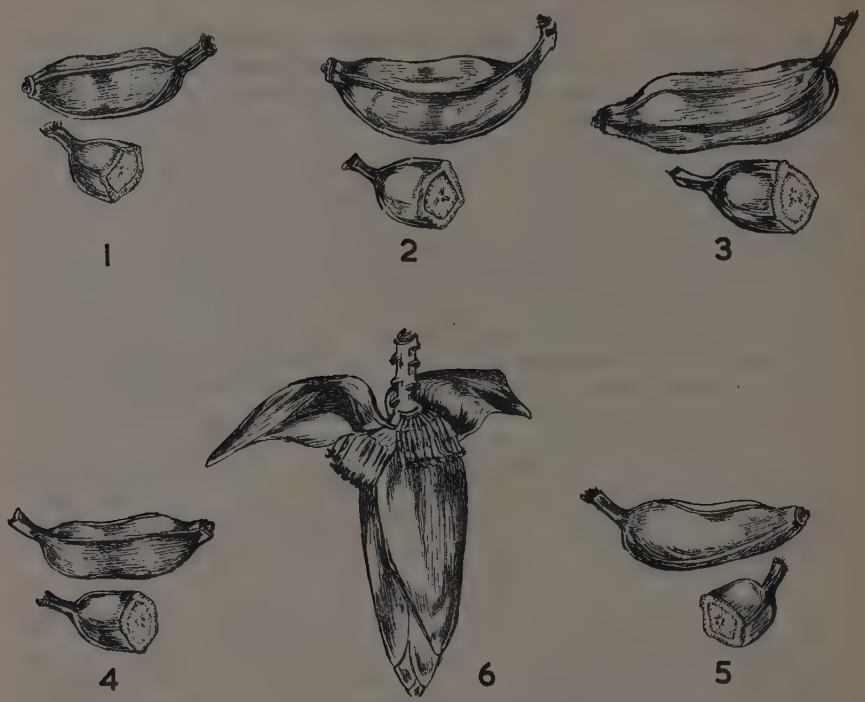

FIG. 2. *THE PEYAN GROUP*—1. PEYAN, 2. BOOTHI BALE, 3. KOSTHA BONTHA, 4. PEY KUNNAN, 5. ALSHI, 6. MALE BUD OF PEYAN

Inflorescence: Pendulous and glabrous, coloured dark green, with two sterile bracts, which are greenish purple in colour, the first showing foliage characters, the bracts with fruiting flowers coloured brick-red with yellow blotches, waxy bloom profuse, longitudinal grooves prominent only in the basal half, inner colour of bracts uniformly crimson.

Female flowers: Biseriate; *united tepal:* coloured pink with hyaline margin, 5·0 to 5·2 cm. in length, 2 to 2·3 cm. in breadth, five lobed, lobes yellowish in colour; *free tepal:* light suffused pink or deep pink; *staminodes:* five, filament 2·1 cm. in length, white, anthers rudimentary; *pistil:* ovary three to five sided, angular, pale green, with or without ashy bloom; *style:* 4·3 cm. to 4·5 cm. in length, white; *stigma:* capitate, big and dark brown.

Male bud: conical and linear, imbricate, outer colour of bracts brick-red, with profuse ashy bloom, longitudinal grooves prominent only towards the basal half, inner colour of bracts uniformly crimson, bracts and male flowers deciduous.

Male flowers: Biseriate; *united tepal:* coloured pink with hyaline margin, 4·5 to 4·7 cm. in length, 2 to 2·1 cm. in breadth, five lobed, yellow; *free tepal:* transluscent with light suffused pink or deep pink.

Stamens: Filament 2·0 to 2·1 cm. in length, white, anther lobes 2·4 to 2·6 cm. in length, dark pink; *pistillode:* aborted, ovary conical, white in colour, style 4·0 to 4·2 cm. in length, white, stigma capitate, small, yellow in colour.

Bunch: Pendulous, peduncle glabrous, fruit bearing axis 35 to 47 cm. in length, 10-13 hands, wrist very prominent, bunch compact; *fruits:* angular, may be compressed, fruits medium to small, apex nipple-shaped or tapering, skin 0·3 to 0·4 cm. in thickness, colour at maturity dark green or glistening and glaucous, yellow on ripening, the mesocarp sticks to the flesh in threads when peeled, flesh white, aborted seeds visible; keeping quality good; fruits strongly attached to pedicel, dessert quality good. *Suckering*: six to eight suckers; duration 352-532 days.

Varieties, Types and Synonyms

1. *Peyan.* Syn. *Bhurkel:* A tall plant, 286-468 cm. in height, 61-85 cm. in girth, pseudostem dark green, midrib green on both surfaces, floral parts including free tepal pigmented; *bunch:* semi-pendant, 16-25 lb. in weight, number of hands 7-12, number of fruits 121-162; *fruits:* small, length of edible portion 10 cm., girth 12·8 cm., pedicel 3 cm. in length, and apex 1·3 cm. in length, fruits angular and compressed, tapering to apex, waxy bloom sparse, rind very thick, 0·4 cm. in thickness, dark green on maturity with light ashy bloom; average duration 527 days.

2. *Boothi Bale.* Syn. *Kanthali Kela:* This variety varies from *Peyan* in its pale green pseudostem and profuse ashy bloom on the rind which is also pale green in colour; average duration 530 days.

3. *Kostha Bontha.* Syn. *Raja Vazhai:* A tall plant, 300-398 cm. in height, 60-82 cm. in girth, mid-rib flesh-coloured on the lower surface, leaves distinctly arched, free tepal transluscent white, occasionally with light suffused pink tinge; *bunch:* pendant and compact, 20-35 lb. in weight, number of hands 8-13, wrist prominent, number of fruits 100-195; *fruits:* angular but not compressed, skin glistening and glaucous, apex very distinct, length of edible portion 12·9 cm., girth 12·0 cm., pedicel 3·5 cm. and apex 2·2 cm. in length, fruits distinctly reflexed and negatively geotropic; average duration 532 days.

4. *Pey Kunnan.* Syn. *Venneettin Mannan, Chinia:* Plants 291-331 cm. in height, 51-60 cm. in girth, leaves well spread, mid-rib flesh-coloured on the lower surface, free tepal transluscent white or light suffused pink occasionally; *bunch:* pendulous and compact, 22-29 lb. in weight, number of hands 7-13, wrist prominent often only in a few hands where reflexion of fruits is very prominent; *fruits:* resemble *Kostha Bontha* in shape, length of edible portion 10·2 cm., girth 10·1 cm., pedicel 3·3 cm. in length and apex 1·9 cm.; average duration 419 days.

5. *Alshi.* Syn. *Thote, Onakkan Mannan:* Plants tall, 280-310 cm. in height, 50-56 cm. in girth, pseudostem pale green, leaves well-spread, mid-rib flesh-coloured; *bunch:* pendulous and rather compact, 13 to 23·5 lb. in weight, number of hands 6-12, wrist prominent often only in a few hands; *fruits:* not distinctly reflexed, in shape resemble that of *Kostha Bontha*, length of edible portion 9·1 cm., girth 10·3 cm., pedicel 2·0 cm. and apex 1·5 cm. in length; average duration 352 days.

DISCUSSION

Recent attempts at classification of bananas have been directed towards tracing the origin of most horticultural varieties to either *Musa balbisiana* Colla or *Musa accuminata* Colla which are recognised as the two progenitors of the *Eumusa* section or to a third group exhibiting an admixture of the characters of these two species. Each of these groups claims a large number of cultivated banana varieties. The *Monthan* and the *Peyan* groups of bananas dealt with in this paper may be said to be typical of *Musa balbisiana* with little or no resemblance to *Musa acuminata*. Among the more important traits in support of the resemblance to *Musa balbisiana* are: (i) the characteristic robust growth of the plants with height ranging from 210-445 cm. and the girth of the pseudostem from 44-81 cm., (ii) green or yellowish green pseudostem, (iii) profuse ashy bloom in the young regions and near the petioles, (iv) incurved petiole margin with bluish brown tinge, (v) leaf sheath clasping the pseudostem tightly, (vi) tough texture of the lamina, (vii) distinctly pigmented flowers, (viii) inner colour of bracts uniformly crimson, (ix) thick rind of fruits, (x) strong adherence of fruit proper to pedicel, and (xi) white flesh.

This hypothesis is further strengthened by the fact that both *Monthan* and *Peyan* groups of varieties are the most drought-resistant among bananas, a character typifying the *balbisiana* group [Simmonds, 1956]. Besides all the above which are common to both *Monthan* and *Peyan* groups, the latter is characterised by a flavour of its own which is again associated with *Musa balbisiana*.

In classifying the varieties into two groups *Monthan* and *Peyan*, the following identifying characters have been considered:

1. The use of the fruit: culinary varieties under *Monthan* and dessert varieties under *Peyan*
2. Presence of prominent wrist in the hand identifying the *Peyan* group and its absence the *Monthan* group
3. Heart shape: ellipsoid or ovoid for *Monthan*, and conical and linear for *Peyan*
4. Angular fruits distinctly compressed identifying the *Monthan* group
5. Apex distinctly tapering characterising the *Monthan* group
6. Characteristic flavour of fruits in the *Peyan* group and
7. Sticky vascular strands in the mesocarp remaining as threads on the flesh in the *Peyan* group.

In addition to the above characters which are by themselves adequate to determine the relationship of the varieties under the *Monthan* and *Peyan* groups, an important confirmatory evidence appeared to be the extent of female fertility of the varieties. The preliminary studies on hybridization at the Central Banana Research Station, Aduthurai, have shown that the *Peyan* group is highly female fertile and compatible with *Musa balbisiana*, a feature noteworthy when compared to the low fertility of the *Monthan* group.

On all the above considerations, it has been found possible to group all the 18 varieties dealt with into either of the two categories, viz. *Monthan* or *Peyan*. With regard to three varieties, viz. *Ney Mannan*, *Pey Ladan*, and *Mayil Vazhai*, how-

ever, some explanation appears necessary, if only to dispel a possible misapprehension that they may as a group resemble *Peyan* because of the similarity in the shape and size of the fruits. A detailed study of the several morphological characters listed above and in particular the predominant culinary property, a total lack of dessert quality, absence of wrist (which cannot be associated with *Peyan*), the relatively low fertility of these varieties as compared to those under the *Peyan* group, conclusively prove that these three varieties should rightly be classified under the *Monthan* group. On these grounds, therefore, Jacob's [1952] grouping of *Mayil Vazhai* and *Pey Ladan* under '*Peyan*' and of *Ney Mannan* as a third distinct group are open to question. The status of *Ney Mannan* has also been dealt with by Nair *et al.* [1957], whose views are in agreement with the authors' observations.

The possibility of according a special status to the varieties intermediate in shape and size between *Monthan* and *Peyan* by recognising a third group was also examined thoroughly, but found unjustifiable, because these varieties exhibited unmistakable resemblance to the *Monthan* group. Secondly, minor variations within the varieties were noticed and the lack of uniformity could not, obviously tend support to a claim of a group status for these varieties.

SUMMARY

Detailed descriptions of the *Monthan* and the *Peyan* groups of bananas are given. Synonyms and identifying characters of varieties and types have been listed out. The systematic status of the groups is discussed.

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A NOTE ON THE REVERSION OF A BANANA MUTANT

(VARIETY *THATTILLA KUNNAN*)

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Somatic mutations are often a cause for the production of new varieties in *Musa*. One of the common types of mutations is that affecting stature. Thus, in the Cavendish group, there are dwarf, semi-tall and tall forms (1). Similar sports occur with regard to the abortion of the male bud. The variety *Moongil* which is akin to *Nendran* or the Horn plantain (3), *Ayiranka Rasthali* which is a sport of *Rasthali* and *Thattilla Kunnan*, a mutant form of *Thenkunnan* are a few examples. Except for the fact that in *Ayiranka Rasthali* occasionally naked portions occur between female phases, these mutant types of bananas are hitherto thought to have been stable. The present note gives an instance wherein the production of the male bud was noted in *Thattilla Kunnan* (Syn. *Koombilla Poovan*, *Maniyilla Kunnan*, *Mambilla Poovan* and *Poovilla Vazhai*) all suggesting the absence of the male bud in the variety. In the allied *Kunnan* types (2), *Ayiran Kunnan* is reported to be an unstable type of *Kunnan*.

The particular plant, wherein the reversion was noticed, is of the third generation, inflorescences produced in the first and second generation being quite true to the variety. The bud was found to be slightly twisted and split on one side exposing the central core. In *Then Kunnan*, the heart is normally conical but elongated, bluish purple in colour and the bracts do not extend to the apex. In this particular sport, the size of the heart was found to be considerably reduced but in colour and shape no difference could be noticed from that of *Then Kunnan*. The bracts subtending the male flowers were found to be thick and brittle with edges neatly folded inwards.

The male flowers were five to eight in number and resembled that of *Then Kunnan*. In one particular ' hand ', all the flowers were found to be united along the pistillode and united tepal. In a single flower of the united cluster of male flowers, eight stamens and two styles were visible.

The instance given above indicates that reversions of the mutant types are also quite possible, though the frequency with which they occur is not innumerable.

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CACAO PROPAGATION BY INARCHING AND LAYERING

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Cacao is said to have been introduced at Burliar Fruit Station on the Nilgiris in 1851 by Thomas. A study of the yield performance of the existing trees at this and the neighbouring Kallar Fruit Station has shown wide variation in yields of individual trees and has brought out the need for building up clonal progenies from the promising trees. Towards this end, propagation studies to include inarching and layering were undertaken, with the facilities offered by a special scheme of research on clove, nutmeg and cacao. The results of this work have been presented in this paper.

REVIEW OF WORK

Seedling propagation resulting in the degeneration of varieties to types with interbred characters in colour and quality of bean, bearing, growth and hardiness in varying degrees led earlier workers like Hart [1908], Jones [1909] and Smith [1911] to conclude that any real improvement in cacao could be effected only through clonal propagation of superior types. They further found grafting and budding to be feasible. Jones [1909] has standardised the technique of inarching which he found feasible to be adopted all through the year, the wet season being the most optimum and economical. Hart [1908] and Jones [1909] found inarches to be slightly costlier than seedlings but by skilful management the expenses could be reduced.

Evans [1951] has standardised marcotting methods after undertaking trials to induce rooting of shoots while yet on the tree with and without hormone or foliar treatment of shoots had failed. Naundorf [1951] found air-layering by use of 0·25 per cent of alph-naphthalene acetic acid in a paste form highly successful. Pyke [1934] found that ' chupons ' could be successfully stooled or etiolated, and that ' fans ' could be layered which developed into low branching bushes. Attempts to air layer the cacao by cincturing at Kallar Fruit Station in 1947-1948 ended in failure, though the development of a callus pad at the treated portion of the shoots was pronounced.

MATERIAL AND METHODS

Trials on inarching and layering in a medium of sandy loam and compost in equal proportions in earthen pots by ringing, and ringing and cincturing using polythene (Alkathene 150 gauge) and banana sheath wrappers in wet moss medium, without any hormone treatment were conducted at monthly intervals over a period of one year on selected consistently high yielding trees at the rate of ten for each treatment to determine the optimum season and technique for operations.

For inarching, well grown, healthy and vigorous seedlings eight to ten months of age and 0·7 to 0·9 cm. thick planted in pots were used. Bamboo stages were put up on vertical supports under the scion trees to hold the stock seedlings. The wood was carefully sliced off to a thickness of one third of the parts of the scion and the

stock operated about three inches in length and the cut surfaces fitted closely and fastened firmly together by wax cloth and jute fibre. The graft joint was then wrapped over with clay and dung poultice. Union between stock and scion was observed at the end of 90 days and the graft was gradually separated in stages after 90, 105 and 120 days of inarching.

Layering without any hormone treatment was done by ringing and cincturing of shoots. Ringing was done in a medium of sandy loam and compost, in equal proportions in earthen pots, and in polythene (Alkathene 150 gauge) and banana sheath wrappers in wet moss medium by removing the bark of the shoot treated to $\frac{1}{2}$ to 1 inch in length. Cincturing was done in polythene (Alkathene 150 gauge) and banana sheath wrappers in wet moss medium by removing the bark of the shoot treated to 1/8 to 1/4 inch in length.

RESULTS

Inarching: The particulars of ' take ' recorded in the trial on inarching are given in Table I.

TABLE I. TAKE RECORD IN THE TRIAL ON INARCHING

Period	Number done	Number separated successfully	Percentage of 'take'	Number of days taken for union
November, 1955	10	10	100	120
December, 1955	10	10	100	120
January, 1956	10	9	90	120
February, 1956	10	10	100	90
March, 1956	10	10	100	120
April, 1956	10	10	100	120
May, 1956	10	10	100	120
June, 1956	10	9	90	120
July, 1956	10	7	70	120
August, 1956	10	9	90	100
September, 1956	10	8	80	120
October, 1956	10	8	80	120

The ' take ' was high ranging from 70 to 100 per cent all through the year, the few failures being either due to operational defects or due to mechanical injury to the scion. The period required for complete union was seen to range from 90 to 120 days, the time taken in February operations being as low as 90 days against 100 days in August operations.

Observation trials on wrapping over the graft joint after preliminary bindings with wax cloth and jute fibre by polythene wrapper (Alkathene 150 gauge) in place

of the clay dung poultice during January 1957 have shown that the union was completed even in 75 days of operation enabling separation of the grafts successfully in 90 days, thus considerably shortening the period of ' take ' and costs of production.

Layering

The data on the number of days taken for callusing, eventual separation, the percentage and number of layers rooted under the different treatments in the trial are given in Table II.

TABLE II. EFFECTS OF DIFFERENT TREATMENTS ON THE LAYERING OF CACAO

Period of Layering	No. done	Number of days taken for callusing					Number of days taken for separation					Percentage of layers rooted (No. of rooted layers in brackets)				
		Ringing			Cincturing		Ringing			Cincturing		Ringing			Cincturing	
		Earthen pots	Polythene	Banana sheath	Polythene	Banana sheath	Earthen pots	Polythene	Banana sheath	Polythene	Banana sheath	Earthen pots	Polythene	Banana sheath	Polythene	Banana sheath
September, 1955	10	65	50	85	45	90	200	225	..	..	..	40(4)	30(3)	(0)	(0)	(0)
October, 1955	10	70	65	80	62	60	160	195	..	..	..	30(3)	10(1)	(0)	(0)	(0)
November, 1955	10	55	45	85	40	60	165	165	..	..	..	40(4)	20(2)	(0)	(0)	(0)
December, 1955	10	60	40	90	55	60	130	130	..	135	..	60(6)	30(3)	(0)	10(1)	(0)
January, 1956	10	30	35	25	26	60	150	120	..	..	..	80(8)	20(2)	(0)	(0)	(0)
February, 1956	10	30	18	75	18	30	120	120	..	120	..	80(8)	40(4)	(0)	20(2)	(0)
March, 1956	10	18	22	75	27	90	120	120	..	90	60	60(6)	50(5)	(0)	40(4)	10(1)
April, 1956	10	24	25	75	30	60	90	100	120	90	60	60(6)	70(7)	20 (2)	70(7)	10(1)
May, 1956	10	20	18	60	30	30	90	70	..	75	60	100(10)	80(8)	(0)	90(9)	20(2)
June, 1956	10	20	23	65	30	30	90	60	..	60	..	80(8)	90(9)	(0)	70(7)	(0)
July, 1956	10	20	20	70	30	30	80	60	..	60	60	80(8)	80(8)	(0)	40(4)	(0)
August, 1956	10	20	20	75	30	30	80	60	..	60	..	60(6)	70(7)	(0)	90(9)	(0)

Callus formation was observed in all the treatments within about 30 days of operation (excepting in ring layers in banana sheath wrapper) during January to August as against 45 to 60 days taken during September to October. The banana sheath

wrapper was observed to deteriorate rapidly followed by the drying up of the moss inside resulting in the development of a thick basal callus pad in the treated shoots due to dessication of the moss and excessive aeration.

The period taken for rooting and eventual separation was about 120 days in layers raised in pots as against 60 to 86 days by cinctures on an average. The period required for root development and separation from February to August, ranged from 70 to 120 days during the flushing and growing season of cacao at Kallar. Rooting was observed to be quicker during the season of the wet flush from May to August while it took a little time more during the season of the dry flush from February to April, greater quantity of rain being received during the former period.

In the analysis of variance of the angle of rooted layers (angle=arc sin $\sqrt{\text{percentage}}$), the treatments and the months were observed to have come off highly significant at 1 per cent level.

Ringing in pots and polythene (Alkathene 150 gauge) wrapper was found to be the best followed by cincturing in polythene wrapper. May seems to be the best month for layering followed by April and June, July and August, and February and March respectively in the order given. The period from February to August is found to be the optimum for layering as judged from the number of layers rooted (Appendices I, II and III).

The observations on the period taken for rooting and eventual separation are also in conformity with the results of the analysis of variance.

Cost of production of clonal progenies and seedlings: The cost of production of clonal progenies by inarching and layering by different methods in comparison with seedlings is presented below:

Inarches

Cost of 100 cacao seedlings in earthen pot containers at Re. 0-4-0 each	Rs. 25	0	0
Raising bamboo stages (12ft. × 8ft. × 5ft.) at Rs. 6-0-0 each	Rs. 24	0	0
Labour for inarching at Rs. 1-4-0	Rs. 2	8	0
Watering for four months at Rs. 2-8-0 per mensem	Rs. 10	0	0
Total cost of production for 95 inarches (giving allowance for failures)	Rs. 61	8	0

Cost per inarch Re. 0-10-6 (approximately)

Layering in pots

Cost 100 earthen pots of 8 in. size at Rs. 13-8-0	Rs. 13	8	0
Labour for ringing in at Re. 0-14-0 ..	Rs. 1	12	0
Separating and potting charges at Re. 0-14-0	Rs. 0	14	0
Watering charges for five months at Rs. 2-8-0 per mensem	Rs. 12	8	0
Total cost for 90 rooted layers (giving allowance for failures)	Rs. 28	10	0

Cost per pot layer Re. 0-5-0 (approximately)

Air layering by ringing

Cost of 4 oz. of polythene (Alkathene 150 gauge) film at Re. 0-7-0 per oz.	Rs.	1	12	0
Cost of 8 lb. of moss at Re. 0-2-0 per lb.	Rs.	1	0	0
Labour for layering at Re. 0-14-0	Rs.	1	12	0
Cost of 90 earthen pots of 8 in. size at Rs. 13-8-0 per 100	Rs.	12	2	0
Separating and potting charges for 90 layers giving allowance for failures	Re.	0	14	0
Watering for two months at Rs. 2-8-0 per mensem (after separation)	Rs.	5	0	0
Total cost for 90 layers	Rs.	22	8	0
Cost per layer — Re. 0-4-0 each				

Seedlings

Cost of 100 seeds, i.e. five pods at Re. 0-0-6 per pod	Re.	0	2	0
Labour for raising nursery bed (5ft. × 4ft. × 6in.) and sowing	Re.	0	10	0
Watering and weeding charges at one anna per day for four months	Rs.	5	0	0
Cost of 80 rattan baskets 8 in. size at Rs. 18-12-0 per 1,000	Rs.	1	8	0
Lifting and potting charges for 80 seedlings, giving allowance for non-germination and casualties	Rs.	1	0	0
Watering for one month after potting	Rs.	1	6	0
Total cost for 80 seedlings	Rs.	9	10	0
Cost per seedling — Re. 0-2-0 each				

It is seen that seedlings cost two annas each, being the cheapest, while air or pot layers cost about four annas each and inarches 10½ annas each respectively.

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APPENDIX I

Cacao Layering Trial (1955-1956)

Period	No. done	Percentage of rooting (No. of layers rooted in brackets)					Angle of rooted layers (Angle=arc sin $\sqrt{\text{Percentage}}$)					
		Ringing in			Cincturing in		Ringing in			Cincturing in		
		Earthen pots	Poly-thene	Banana sheath	Poly-thene	Banana sheath	Earthen pots	Poly-thene	Banana sheath	Poly-thene	Banana sheath	Total
September, 1955	10	40(4)	30(3)	(0)	(0)	(0)	39·23	33·21	0	0	0	72·44
October, 1955	10	30(3)	10(1)	(0)	(0)	(0)	33·21	18·44	0	0	0	51·65
November, 1955	10	40(4)	20(2)	(0)	(0)	(0)	39·23	26·56	0	0	0	65·79
December, 1955	10	60(6)	30(3)	(0)	10(1)	(0)	50·77	33·21	0	18·44	0	102·42
January, 1956	10	80(8)	20(2)	(0)	(0)	(0)	63·44	26·56	0	0	0	90·00
February, 1956	10	80(8)	40(4)	(0)	20(2)	(0)	63·44	39·23	0	26·56	0	129·23
March, 1956	10	60(6)	50(5)	(0)	40(4)	(0)	50·77	45·00	0	39·23	0	135·00
April, 1956	10	60(6)	70(7)	20(2)	70(7)	10(1)	50·77	56·79	26·56	56·79	18·44	209·35
May, 1956	10	100(10)	80(8)	(0)	90(9)	10(1)	90·00	63·44	0	71·56	18·44	243·44
June, 1956	10	80(8)	90(9)	(0)	70(7)	20(2)	63·44	71·56	0	56·79	26·56	218·35
July, 1956	10	80(8)	80(8)	(0)	40(4)	(0)	63·44	63·44	0	39·23	0	166·11
August, 1956	10	60(6)	70(7)	(0)	90(9)	(0)	50·77	56·79	0	71·56	0	179·12
					Total		658·51	534·23	26·56	380·16	63·44	1662·90
								C.F. 46,087·27				(60)

APPENDIX II

ANALYSIS OF VARIANCE OF ANGLE OF ROOTED LAYERS

Due to	D.F.	S.S.	M.S.	F.	Significance
Treatments	4	26,270·13	6,567·53	39·99	Highly significant at 1 per cent
Months	11	9,153·24	832·11	5·07	
Error	44	7,226·43	164·24		
Total	59	42,649·80			

S. error per plot $= \sqrt{164 \cdot 24} = 12 \cdot 82$ General mean 27·7150

	Treatments	Months
S.E. (Mean)	$= \frac{\sqrt{164 \cdot 24}}{12} = 3 \cdot 70$	$\frac{\sqrt{164 \cdot 24}}{5} = 5 \cdot 73$
S.E. of the difference of two means	$= 3 \cdot 70 \times 1 \cdot 4142 = 5 \cdot 23$	$5 \cdot 73 \times 1 \cdot 4142 = 8 \cdot 10$
C.D. (5 per cent)	$= 5 \cdot 23 \times 2 \cdot 02 = 10 \cdot 56$	$8 \cdot 10 \times 2 \cdot 02 = 16 \cdot 36$
Conclusion	Ringing in pots 54·88	May 48·69
		June 43·67
	Ringing in polythene 44·52	April 41·87
		August 35·82
		July 33·22
	Cincturing in polythene 31·68	March 27·00
		February 25·85
		December 20·48
		January 18·00
		September 14·49
		November 13·16
		October 10·33

APPENDIX III

Presentation of means and summary of results

Month	Ringing			Cincturing		Total	Mean angle	Per cent of rooted layers	No. of rooted layers	Percentage over general mean	Remarks
	Earthen pots	Polythene	Banana sheath	Polythene	Banana sheath						
September, 1955	39·23	33·21	0	0	0	72·44	14·49	6·3	1	50	
October	33·21	18·44	0	0	0	51·65	10·33	3·2	0	0	
November	39·23	26·56	0	0	0	65·79	13·16	5·2	1	50	
December	50·77	33·21	0	18·44	0	102·42	20·48	12·32	1	50	
January, 1956	63·44	26·56	0	0	0	90·00	18·00	9·6	1	50	
February	63·44	39·23	0	26·56	0	129·23	25·87	19·0	2	100	FAIR
March	50·77	45·00	0	39·23	0	135·00	27·00	20·6	2	100	FAIR
April	50·77	56·79	26·56	56·79	18·44	209·35	41·87	44·6	4	200	Better
May	90·00	63·44	0	71·56	18·44	243·44	48·69	56·4	6	300	Best
June	63·44	71·56	0	56·79	26·56	218·35	43·67	47·7	5	250	Better
July	63·44	63·44	0	39·23	0	166·11	33·22	30·0	3	150	Good
August	50·77	56·79	0	71·56	0	179·12	35·82	34·3	3	150	Good
Total	658·51	534·23	26·56	380·16	63·44	1662·90					
Mean angle	54·88	44·52	2·21	31·68	5·29	27·72	27·72	21·6			
Per cent of rooted layers	66·90	49·20	0·15	27·60	0·85	21·60					
No. of rooted layers	7·00	5·00		3		2			2		
Per cent over G.M.	350	250		150	0						

Conclusion : In the analysis of variance the treatments and the month have come off highly significant at 1 per cent level.

Ringing in pots, polythene wrapper is found to be the best followed by cincturing, in polythene wrapper. May seems to be the best month for layering, followed by April and June, July and August, and February and March in the order given.. The period from February to August is the optimum for layering judged from the number of layers rooted.

PREVENTION OF FUNGAL SPOILAGE IN MANGO PICKLE WITH CHEMICAL PRESERVATIVES

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A wide variety of pickles are prepared in the country from different fruits and vegetables, but pickle from green and raw mangoes is the most common. Appreciable quantities of mango pickle are prepared almost in every home. The commercial preparation of this pickle for local sale as well as for export has also lately assumed large proportions. The pickle is usually stored over long periods and very often it is observed that the cause of spoilage is due to the growth of moulds and yeasts. The pickle, thus, affected by fungi becomes soft and also suffers a loss in colour and flavour.

The susceptibility of mango pickle to fungal attack and the efficacy of various condiments to control this spoilage has been investigated by Prasad and Joshi [1929], and Anand and Johar [1952, 1957]. Among the various condiments used in pickle recipes only cloves and cinnamon possessed antifungal properties when used in small proportions. Other condiments had little or no effect at levels at which they are invariably used in pickle recipes. Further work by Anand and Johar [in press] has shown that acetic acid up to a maximum of 0·4 per cent can be used in pickle with advantage to control fungal spoilage. Other acids like lactic and citric were found to be ineffective even at 5·0 and 20 per cent levels respectively.

Chemical preservatives like sulphur dioxide, benzoic, sorbic and propionic acids and their salts, are invariably used all over the world to preserve various types of food products. Their relative efficacy as preservatives, the effective radicals responsible for their inhibitory properties, their minimum concentrations as affected by the nature of the substrate, etc. have been thoroughly reviewed by different workers [Wyss, 1948; Schelhorn, 1953; Dunn, 1954; Rahn and Conn, 1944; Ingram, 1948; and Melnick *et al.*, 1956]. In India, sulphur dioxide, benzoic acid and their salts have been permitted [Fruit Products Order, 1955] for use up to certain limits in the preservation of various fruit products. In pickles, only sodium benzoate up to 0·025 per cent (250 p.p.m.) is permitted. Since this limit for sodium benzoate has been fixed tentatively and is not based on any experimental evidence, it was considered useful to investigate the relative efficacy of sodium benzoate along with other preservatives to control spoilage in mango pickle.

MATERIAL AND METHODS

Preparation of pulp: As there is a wide variation in the composition of green mangoes from fruit to fruit and even on the different parts of the same fruit, it was considered desirable to use homogenised green mango pulp as a substrate instead of small mango slices. The fruits were washed, destoned, sliced, minced and the pulp was filled into hermetically sealed containers and stored at −15°C. as described

in an earlier communication [Anand and Johar, 1957]. Each time before use, the frozen pulp was thawed and removed aseptically from the can. The pulp on analysis (wet basis) gave: moisture, 83·6 per cent; acidity (as citric acid) 2·95 per cent; reducing sugars, 1·3 per cent; Vitamin C, 45 mg./100 gm.; tannins and colouring matter 0·046 per cent. Its *p*H (at 20°C.) was 2·78.

TABLE I. EFFECT OF SODIUM BENZOATE, SODIUM PROPIONATE, SORBIC ACID AND SULPHUR DIOXIDE ON THE GROWTH OF *ASPERGILLUS NIGER* AND ON YEAST IN MANGO PULP

Amount of salt gm./100 gm. pulp	Amount of chemical preservatives added in salted pulp											
	Sodium benzoate (p.p.m.)			Sodium propionate (p.p.m.)			Sorbic acid (p.p.m.)			Sulphur dioxide (p.p.m.)		
	(100)	(200)	(500)	(2,000)	(3,000)	(4,000)	(200)	(500)	(750)	(50)	(100)	(200)
M	+	—	—	+	—	—	+	—	—	+	—	—
0 —												
Y	+	+	—	+	+	—	+	+	—	+	+	—
	(25)	(100)	(200)	(500)	(1,000)	(2,000)	(50)	(100)		(0)	(50)	
M	+	—	—	+	—	—	+	—		+	—	
8 —												
Y	+	+	—	+	+	—	+	—		+	—	
	(0)	(50)		(0)	(100)		(0)	(50)		(0)	(25)	
M	+	—		+	—		+	—		+	—	
16 —												
Y	+	—		+	—		+	—		+	—	

M—Mould; Y—Yeast; + Growth positive; — no growth; (p.p.m.) part per million parts.

Preparation of inocula: Strains of an *Aspergillus niger* and a yeast isolated from spoiled mango pickles were used as test organisms. Conidia and cell suspensions from *A. niger* and yeast respectively were prepared on Acid Dextrose Agar as discussed earlier [Anand and Johar, 1957]. The final suspensions were standardized to give a count of 10^7 cells or spores per ml.

Use of salt and preservatives: Powdered sodium chloride having 97·0 per cent (dry basis) marine chloride was mixed thoroughly at desired levels in thawed pulp. In weighed quantities of salted pulp (20 gm.) in glass stoppered bottles (4 oz. capacity) requisite proportions of chemical preservatives of C.P. quality were thoroughly mixed. Potassium meta-bisulphite was checked each time before addition for its sulphur dioxide content. Two standard loopfuls of mould spores or yeast suspension were added in each bottle and mixed. This gave a final count of 10^4 mould spores or yeast cells per gm. of pulp. The samples of inoculated pulp in stoppered bottles were incubated at room temperature (28-30° C.) in darkness. Growth of yeast in the pulp

was evidenced by characteristic estery odour along with slimy growth on the surface whereas mould growth formed a white matted tuft followed by dark colour fruiting heads. Samples were incubated for at least eight weeks before declaring them free from spoilage. Control lots were run for each treatment as checks for any extraneous contamination.

RESULTS AND DISCUSSION

The data compiled in Table I show the required concentrations of preservatives to control the overall growth of both the mould and the yeast in mango pulp containing different levels of salt. At the same level of concentration, sulphur dioxide is the most effective preservative followed by sodium benzoate, sorbic acid and sodium propionate respectively. It is also evident from Table I that these preservatives are more effective against mould than the yeast although the inhibiting levels for each one of them against the mould vary widely. In unsalted pulp mould can be controlled at 100 p.p.m. level of sulphur dioxide whereas sodium propionate is effective at a considerably higher concentration, i.e. 3,000 p.p.m. level in the pulp. Sodium benzoate and sorbic acid as mould inhibitors, fall between these two extreme limits.

With the increase in the salt concentration the overall efficacy of these preservatives to inhibit both the mould and the yeast can be improved many fold. Much lower concentrations of these preservatives sufficed to control pickle spoilage in pulp containing 8 gm. salt/100gm. pulp as compared with pulp bereft of salt; the quantities of preservatives could further be reduced by increasing the salt concentration. The salt thus seems to have a very important supplementary role in enhancing the preservative value of the chemicals in mango pickle. Further work on the effect of these preservatives on physico-chemical changes in mango pickle during storage is in progress.

SUMMARY

Mango pickle is often attacked by moulds and yeasts. Among the preservatives tried to control these organisms, sulphur dioxide was found to be most effective followed by sodium benzoate, sorbic acid and sodium propionate respectively. The yeast in pickle was found to be more resistant to these preservatives than the mould. By increasing the concentration of salt in mango pickle, the corresponding level of preservatives to control the spoilage organisms can be reduced considerably.

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VARIATIONS IN THE SEVENTH SEGMENT OF THE FEMALE OF *AULACOPHORA FOVEICOLLIS* LUCAS (THE RED PUMPKIN BEETLE)

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Intraspecific variations in the colour of insects are a very common phenomenon, but variation in the shape and size of the seventh tergite and sternite in female *Aulacophora foveicollis* Lucas is notable. This was first observed by the author while studying the external morphology of this beetle. External organs of *A. foveicollis* other than the seventh tergite and sternite are not very variable nor is there any report even on the variation in the seventh tergite and sternite of any other Chrysomelid beetle. The figures (Fig. 1 A-G) of the seventh tergite and sternite of a few varieties are intended to show the variations in shape. The degree of variability in the size of the seventh tergite and sternite and the frequency distribution of the measurements are shown in two separate graphs (Figs. 2 and 3) by taking the measurements of the length and breadth of the seventh tergite and sternite of 108 specimens in millimetres. All the specimens were collected at Kanpur during the year 1953.

Normally, the seventh tergite in *A. foveicollis* female is funnel-shaped (Fig. 1 A), the anterior margin is broad and the lateral margins gradually converge posteriorly up to anterior 2/3rd part of the tergite and the rest of the 1/3rd part protrudes in the form of a nipple with the distal and more or less round.

The seventh sternite is broad on the anterior margin, the lateral margins converge and the posterior margin is bilobed due to a deep mesial notch with margin plain or emarginate.

Variation in shape: The shape of the seventh tergite varies (Fig. 1 A-G) from the normal shape (A) to triangular (F) or broad (G). The distal ends are either rounded (A), notched (B and C), projectile (D) or pointed (E and F). The posterior margin of the seventh sternite is bilobed having plain margin (A, C and F), emarginated (G), trilobed (B and E) or semi-arc shaped (D).

Variation in size: Variations in the shapes of tergite and sternite result in variation in the size. There is also natural variation in size among individuals of the same shape. As is shown in Fig. 2 and the frequency distribution given below, the length and breadth of the seventh tergite vary respectively from 1·20 mm. to 1·84 mm. and 1·30 mm. to 2·20 mm., the average length and breadth of 108 specimens being respectively 1·56 mm. and 1·79 mm. The length and breadth of the seventh sternite vary respectively from 0·74 mm. to 1·08 mm. and 1·60 mm. to 2·80 mm., the average length and breadth of 108 specimens being 0·89 mm. and 2·33, mm. respectively.

From Fig. 3 it can be seen that the distribution of the measurements is such that the greatest number clusters round the average in the middle and at the extremes there are relatively few measurements.

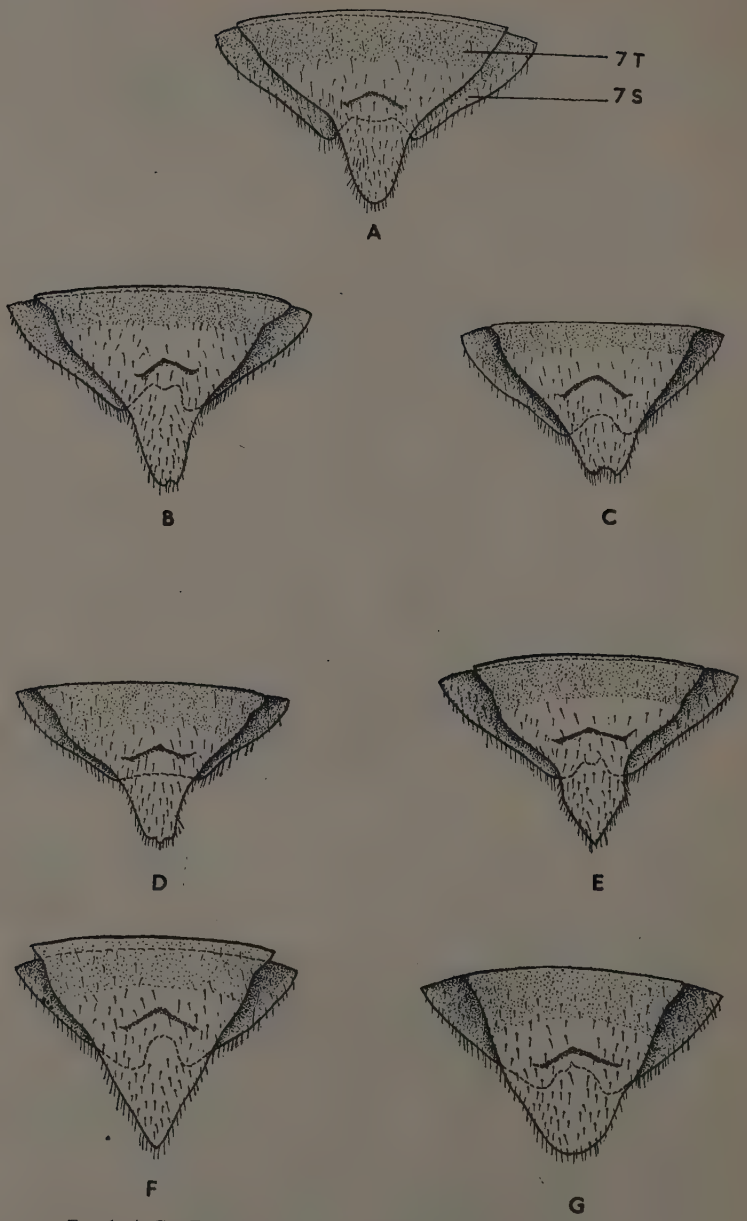

FIG. 1. A–G. DIFFERENT SHAPES OF SEVENTH TERGITE AND STERNITE OF *A. FOVEICOLLIS* LUCAS. S – STERNITE ; T – TERGITE.

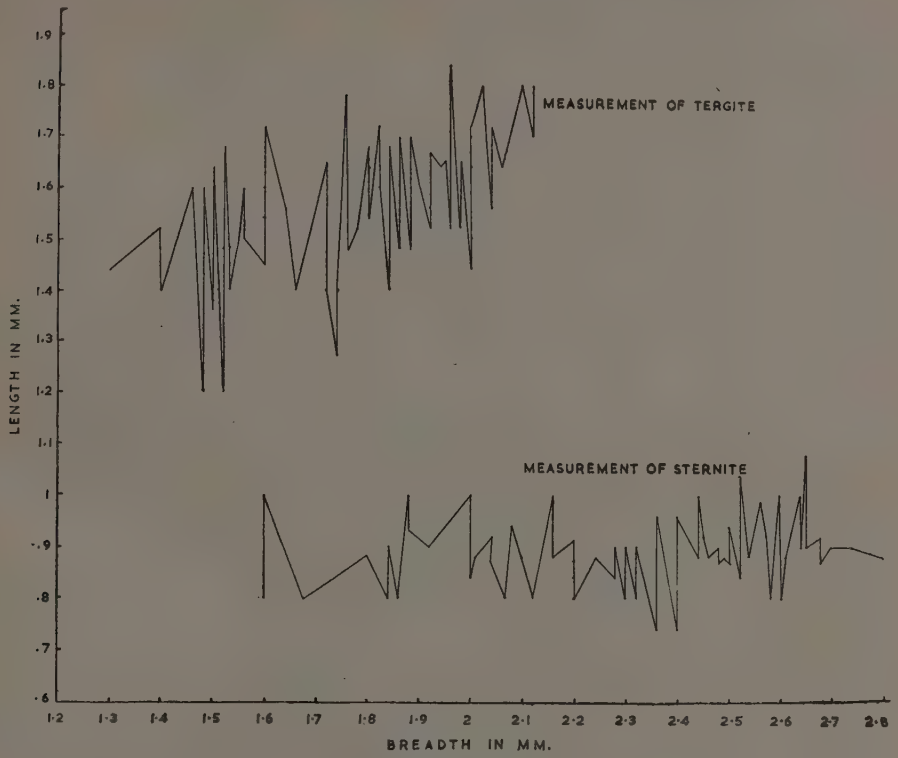

FIG. 2. THE MEASUREMENTS OF THE SEVENTH TERGITE AND STERNITE OF *A. FOVEICOLLIS* LUCAS

In order to compare the relative variability in the length and breadth of the seventh tergite and sternite, their coefficients of variation have been worked out by expressing the standard deviation as a percentage of the mean. The coefficients of variation for length of the seventh tergite and sternite are 12·32 and 6·85 respectively and for the breadth 11·29 and 11·36 respectively. The difference between the former two coefficients is statistically significant but that between the latter two is not significant. Thus, the relative variability for the length of the tergite is much greater than for the length of the sternite, whereas, in the case of breadth, the two vary in more or less the same manner.

The coefficients of correlation between the length of the tergite and the length of the sternite as well as that between the breadth of the tergite and breadth of the sternite have been obtained and are +0·687 and +0·621 respectively. Both these correlation coefficients are statistically highly significant, which establishes that increase in length (or breadth) of the seventh tergite is accompanied by increase in length (or breadth) of seventh sternite.

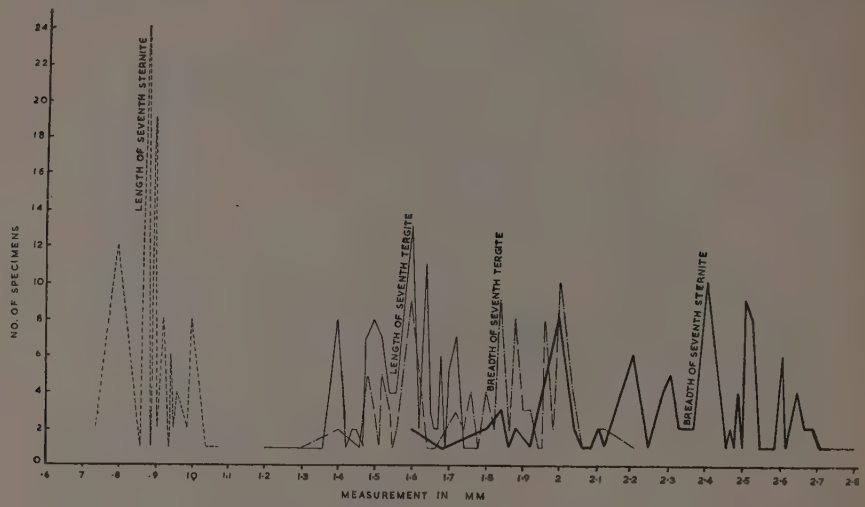

FIG. 3. SHOWING FREQUENCY DISTRIBUTION OF LENGTH AND BREADTH OF SEVENTH TERGITE AND STERNITE IN 108 SPECIMENS

CONCLUSION

Variation in size occurs both in tergites and sternites of the same shape and of varying shapes.

The coefficient of variation for length of the seventh tergite is much greater than that for the length of the seventh sternite, but the relative variability in the breadth is more or less the same for both.

There is a highly significant positive correlation between the lengths of the tergite and sternite, as also between their breadths. Increase in length (or breadth) of the seventh tergite is accompanied by increase in length (or breadth) of seventh sternite.

ACKNOWLEDGEMENTS

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AGRICULTURAL METEOROLOGY*

L. A. RAMDAS

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There is no human activity which is not profoundly affected by weather and climate. That *weather* has a major control over agriculture and crop production has been known ever since man evolved from the hunter into the farmer. The farmer knows that his crop production is a gamble on the rains and on other weather factors like temperature and wind. He has ever watched the skies anxiously for symptoms of coming weather so that he can plan and prosecute his farming operations in consonance with the expected weather.

Agricultural meteorology deals with the various problems of crop growth and out-turn in relation to the environmental factors, i.e. the weather factors and their time sequence during the growing season. These same environmental factors also affect the many crop diseases and pests, and thus bring about a further indirect control over plant growth and yield.

The agricultural experiments recently conducted at experimental farms under expert supervision have confirmed the great importance of the influence of the seasonal variation from year to year. In fact, the variability of crop yields due to weather is found to be of the same order as the variability induced by all the other controls, such as variety, manure and cultural treatments, put together. Again, the acreage sown to crops is known to depend to a considerable extent on weather prior to and during the sowing period. So, just as botany, entomology and chemistry have fundamental contributions of a permanent kind to make to agriculture, so also has the science of meteorology.

In many countries that are primarily agricultural, the official organizations to look after agricultural research and its applications to practical agriculture, and the effect of weather on crops have originated from the incidence of recurring famines due to large-scale failure of the rains. However, in the initial stages, the weather bureaus have confined attention to the organization of networks of weather telegraphing observatories for developing the synoptic weather maps required for predicting the large-scale weather changes from day to day. On the other hand, agricultural statistics of *areas sown* and *yield per acre* have been reputedly unreliable, based as they were on subjective visual estimates of revenue officials whose main purpose was the assessment of land tax. So, though climatic data have been accumulated in some countries over a series of years, these relate to what may be called the macroclimate. We now know that while macroclimate conditions crops, crops too within their own environment control the microclimate, each type of plant community developing its own characteristic deviations from the climate of the open. It seems clear that it is the microclimate that actually controls crop-growth as well as the incidence and intensity

* This article is based on Dr. L. A. Ramdas' address as chairman of the Symposium on Agricultural Meteorology, held on 25 November 1957, during the ninth Pacific Science Congress in Bangkok, Thailand.

of pests and diseases. It is only of late that objective, statistically sound techniques of random sampling have been adopted for estimating crop acreages, crop growth and yields.

The importance of setting up suitable organizations for the systematic investigation of weather in relation to crops began to be realized early in this century and the International Meteorological Organization (now replaced by the World Meteorological Organization) constituted a Commission of Agricultural Meteorology (CAgM) with the object of encouraging these studies in all countries.

After two world wars the nations have come to realize that *food* is indeed a major world problem. The Food and Agriculture Organization of the United Nations, as well as the United Nations Educational, Scientific and Cultural Organization, have taken considerable interest in the problem of maximizing *food production* in all parts of the world and are collaborating with the CAgM in discussing problems of agricultural meteorology and cognate subjects. For the systematic collection of special climatological records side by side with observations of crop growth and yield, the CAgM has prepared detailed technical regulations for use by all interested countries.

It will be realized, of course, that the actual research work and development of this borderland subject has its own history punctuated by the outstanding pioneer contributions of individual scientists and their collaborators. We will now consider some typical or outstanding contributions by way of examples and try to indicate roughly on what lines important developments have taken place and finally suggest in what directions future efforts may be directed.

Microclimates

The investigations of Schmidt and Geiger on the influence of slopes, city environments, forests and the like have become classical. Geiger's book on *The Climate Near The Ground* will ever remain a standard reference on these topics.

In the tropics and sub-tropics the present writer and his collaborators in India have brought out some interesting features of the microclimates of different tropical crops and the way in which temperature and moisture vary inside crops with height and time of day and from simultaneous measurements in an open space. The significant influence of crops at their *canopy* stage in developing thermal inversions even during day-time, when the canopy takes over the functions of an *active surface* in place of the bare ground of the open, has also been investigated.

Reference must also be made to the outstanding contributions made in micrometeorology by O. G. Sutton and his collaborators, which have considerably enriched knowledge in a field which is sure to be of immense benefit to those concerned with the war against harmful insects and diseases which sometimes appear in an epidemic form. Sutton's masterly treatment of these problems in his book on *Micrometeorology* may be referred to here.

The Moisture Factor

The study of the air layers near the ground has naturally led to several critical studies on the diffusion of water vapour, carbon dioxide, and other gases and vapours occurring in atmosphere. In particular, the vertical diffusion of water vapour from

the ground and from lakes and reservoirs sets an important limit to the water resources that may be available for agriculture. It should be emphasized that, of all the factors affecting crop growth, the moisture needed by plants for the transpiration process and the associated transport of essential nutrients to the various parts of the growing plant is perhaps the most important. The vital need for conserving water resources for maximum use in food production for the world's growing population will be obvious. Of late, attempts are being made to check water loss by evaporation by spreading monomolecular layers of organic substances like cetyl alcohol over the large water surfaces of lakes and reservoirs.

The soil moisture available to plants, methods of subsoil irrigation, warnings as to when the next irrigation should be given to a crop, these and other allied topics are under active investigation in many countries.

The pioneer investigations of Thornthwaite, Penman and others have indeed emphasized the urgent need for developing precise experimental techniques for computing evaporation and evapo-transpiration. Rapid progress in this direction is at present being made at many centres of research. Thornthwaite's concepts of evapo-transpiration and potential evapo-transpiration are indeed proving very fruitful in current researches on the water requirements of crops and attempts are being made in some countries to tell the farmer when the next irrigation is due. The need for development of a portable and simple but reasonably accurate instrument to enable the farmer and the irrigation engineer to measure soil moisture quickly and thus find out when the next irrigation is due has been emphasized by WMO. In India, the Council of Agricultural Research has offered a handsome prize for such an instrument. At Poona, Momin has been developing such an instrument which is based on the dependence of the thermal diffusibility of the soil on soil moisture.

Ramdas and co-workers have shown that under conditions when the soil surface contains only hygroscopic moisture, this surface and the air layers above it exchange water vapour between them, the soil giving up moisture by evaporation during the day, and the air layers yielding moisture to the soil surface by invisible condensation and occasionally as dew. These are now recognized as secondary sources of moisture to living plants.

It is well known that plants respond best to an optimum dose of water. So long as wilting does not set in during a prolonged drought, a timely irrigation may still revive a withering crop. And just as in the case of other factors, too much water and continuous flooding would be as disastrous as a prolonged drought.

Temperature Factor

Living plants thrive best at an optimum temperature of about 30-35° C. We have seen that the environmental temperature is conditioned by the microclimate which in turn depends on the heat and moisture balance of the plant community in relation to solar radiation. Below freezing point we have killing frost which is one of the greatest dangers to agriculture. Temperatures approaching the lethal value of 45°C. and above, which cause wholesale withering of crops, do sometimes occur.

Usually, however, a healthy standing crop itself provides a certain shielding effect from the heating effects of solar radiation. This is well illustrated inside a crop

like sugarcane, particularly after it has developed a canopy in the later stages of the crop's growth.

Over bare ground the solar radiation has its full effect and the surface of the ground becomes the source of heating by day and of radiative cooling during night. It is, therefore, the *active surface*. As soon as a crop begins to grow, the ground begins to transfer some of this activity to the screening vegetation and ultimately to the canopy if one is formed by the crop. Under these conditions the diurnal variation of temperature is considerably reduced inside the crop, while humidity retains comparatively high values owing to the isolation of the trapped air inside the crop. These features have been demonstrated in a series of papers by the present writer and his co-workers.

Solar Radiation and Photosynthesis

As is well known, the sun sustains all forms of life on the earth. The injurious ultra-violet radiation from the sun is cut off by atomic oxygen and ozone in the upper atmosphere while a fraction of the incoming radiation is also diffused by the atmosphere. What reaches the surface of the earth provides sufficient energy for sustaining the thermal balance at the earth's surface. Wherever the earth is covered by plants, a small fraction of the incoming visible solar radiation is utilized by plants for photosynthesis—the process by which plants extract the solid carbon from carbon dioxide from the atmosphere in the presence of moisture. Considering that photosynthesis plays a vital role in the plant growth, it is surprising that ordinarily plants utilize not more than 1 per cent of the incoming visible radiation. Obviously, great headway has to be made in increasing the utilization of solar radiation. This potential source of energy for increasing plant growth can be utilized only by algae grown in depth in an aquatic medium. Some of those algae are considered to be edible and may thus supplement the depleted food resources of the earth.

Crop Statistics

It is now generally agreed that past data of crop acreages and out-turns are far from accurate so that it is heartening to note the improvements now being made in the estimation of crop yields by crop cutting experiments in sampling surveys. These data will provide information which could be correlated with the climatic records. Simultaneously, many countries have begun to set up networks of crop-weather stations for estimating crop growth and yield and concurrent meteorological data in sufficient detail so that all environmental factors are recorded during the life-history of the crop. While the micrometeorologist and microclimatologist have made considerable contributions of late in improving the type of environmental information that has to be recorded, the agriculturist, aided by the statistician, has also simultaneously developed efficient techniques for estimating crop growth and yield by random sampling. In developing this aspect of the subject, the school of statistics developed with much success by Professor R. A. Fisher and his collaborators at Rothamsted has been an inspiration to workers in all countries.

Obviously, one of the aims of science is to be able to predict future events from past information. Governments are anxious to obtain crop forecasts, well ahead of

the harvest, based on the previous crop and environmental conditions in different parts of a country. Crop forecasting based upon these relevant factors would be most valuable in planning the production and distribution of food and in assessing the probable income of the financial year. There is still considerable headway to be made in this field but, meanwhile, a provisional forecasting based upon the existing methods is being practised in many advanced countries. Future developments in crop-weather-statistics and crop-weather relations will surely lead to considerable improvement in crop forecasting.

Abnormal Weather

The course of climatic factors during a growing season is by no means as simple and regular as may be suggested by their normal or average values. In any single year these factors deviate at random from the normal values. The weather may change so abruptly and with such violence as to damage or destroy growing crops. It is the duty of agricultural meteorologists to prepare frequencies of various adverse weather phenomena that affect growing crops for the different critical periods of each crop's life-history. The weather forecasters have a very eminent role to play in trying to make available to the farmer weather forecasts and warnings as far ahead as possible, so that the farmer may be in a position to prepare against possible dangers. Weather forecasts for the farmer will surely develop side by side with the progress of weather forecasting as a science and in the not very distant future it is likely that weather forecasts a week or fortnight ahead may become possible. Medium-range forecasting is at the moment under investigation in many countries.

Future Developments

The recent progress of agricultural meteorology enables one to envisage many new developments in the future. The methods being adopted in respect of annual crops may find application and extension to the problems of horticulture and forestry. We have already mentioned possible developments in medium-range forecasting. Then there are problems relating to the maximum utilization of water resources which deserve very high priority.

Weather in relation to animal husbandry also deserves to be explored and developed in the years to come. These problems are naturally more complex and difficult but they deserve early consideration. And then what bigger task can the scientist take up than the study of man in relation to his own environment? What bigger boon can the scientist give to the farmer than warning against large-scale infestation by disease and pests? One need remember only the invasions by locusts and cereal rusts over large tracts of the world to be reminded of the importance of these problems.

Enabling plants to avoid risks due to drought and frosts by producing resistant varieties is the task of the plant breeder. For this purpose as well as for other detailed investigations on crop-weather relations it is likely that work with plants in control chambers, the values of the relevant environmental factors varying from chamber to chamber, is likely to be taken up in many countries. This may help to provide insight into phenomena occurring at random or without control in nature.

Handbook on Agricultural Meteorology

The only book, as such, on this subject is Smith's *Agricultural Meteorology* which is very much out of date. The stage has now been reached when an authoritative textbook on agricultural meteorology should be published. The contents and scope of such a book have been prepared by a working group of CAgM and the matter will be discussed at the second session of this commission in Warsaw.

Instructions to Authors

Articles of agricultural interest are accepted for publication in the *Indian Journal of Agricultural Science*. The manuscript should be neatly typed (double space), and sent in duplicate to the Editor (Research), Indian Council of Agricultural Research, Krishi Bhawan, New Delhi. The articles should not exceed 20 typed pages. Preference will be given to papers containing results of original research. Normally, only one paper by the same author will appear in a single number.

Every paper is scrutinized by a referee. The author is subsequently asked to revise the paper in accordance with the referee's or editor's comments.

Proofs are sent to authors for correction, and these should be returned within seven days of the receipt. Alterations in the proofs leading to an additional payment to the press, will not normally be accepted.

Articles sent for publication should not have been published elsewhere and should be exclusive for this journal. Each article should have a brief summary limited to not more than 350 words.

In the case of botanical and zoological names, the International Rules of Botanical/Zoological Nomenclature should be followed. Generic and specific names should be underlined in the manuscript. In the case of a plant/animal, which is not widely known, the name of the family should be given in brackets.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, subject title, the abbreviated title of the publication, volume, and page numbers. A sample citation is as follows: 'RANDHAWA, M. S. 1936. Marked periodicity in reproduction of the Punjab fresh-water algae. *Proc. Indian Acad. Sci.*, B. **3**: 401-409'.

In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, e.g., (Moore, 1951). When the author's name occurs in the text, the year of publication alone need be given in brackets, e.g., Kashyap (1929).

Illustrations should be limited to minimum considered necessary, and should be made with pen and indelible India ink, for reproduction. Photographs should be on glossy paper, and at least of cabinet size.

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